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THE MECHANICAL ACTION OF LIGHT.[1]

By WILLIAM CROOKES, F.R.S.

TO generate motion has been found a characteristic common, with one exception, to all the phases of physical force. We hold the bulb of a thermometer in our hands, and the mercury expands in bulk, and, rising along the scale, indicates the increase of heat it has received. We heat water, and it is converted into steam, and moves our machinery, our carriages, and our iron-clads. We bring a loadstone near a number of iron-filings, and they move toward it, arranging themselves in peculiar and intricate lines; or we bring a piece of iron near a magnetic needle, and we find it turned away from its ordinary position. We rub a piece of glass with silk, thus throwing it into a state of electrical excitement, and we find that bits of paper or thread fly toward it, and are, in a few moments, repelled again. If we remove the supports from a mass of matter it falls, the influence of gravitation being here most plainly expressed in motion, as shown in clocks and water-mills. If we fix pieces of paper upon a stretched string, and then sound a musical note near it, we find certain of the papers projected from their places. Latterly the so-called "sensitive flames," which are violently agitated by certain musical notes, have become well known as instances of the conversion of sound into motion. How readily chemical force undergoes the same transformation is manifested in such catastrophes as those of Bremerhaven, in the recent deplorable coal-mine explosions, and indeed in every discharge of a gun.

But light, in some respects the highest of the powers of Nature, has not been hitherto found capable of direct conversion into motion, and such an exception cannot but be regarded as a singular anomaly.

This anomaly the researches which I am about to bring before you

[1] A lecture delivered at the Royal Institution.

have now removed; and, like the other forms of force, light is found to be capable of direct conversion into motion, and of being—like heat, electricity, magnetism, sound, gravitation, and chemical action—most delicately and accurately measured by the amount of motion thus produced.

My research arose from the study of an anomaly.

It is well known to scientific men that bodies appear to weigh less when they are hot than when they are cold; the explanation given being that the ascending currents of hot air buoy up the body, so to speak. Wishing to get rid of this and other interfering actions of the air during a research on the atomic weight of thallium, I had a balance constructed in which I could weigh in a vacuum. I still, indeed, found my apparatus less heavy when hot than when cold. The obvious explanations were evidently not the true ones; *obvious* explanations seldom are true ones, for simplicity is not a characteristic of Nature.

An unknown disturbing cause was interfering, and the endeavor to find the clew to the apparent anomaly has led to the discovery of the mechanical action of light.

I was long troubled by the apparent lawlessness of the actions I obtained. By gradually increasing the delicacy of my apparatus I could easily get certain results of motion when hot bodies were brought near them, but sometimes it was one of attraction, at others of repulsion, while occasionally no movement whatever was produced.

I will try to reproduce these phenomena in this apparatus (Fig. 1). Here are two glass bulbs, each containing a bar of pith about three inches long and half an inch thick, suspended horizontally by a long fibre of cocoon silk. I bring a hot glass rod, or a candle, toward one of them, and you see that the pith is gradually attracted, following the candle as I move it round the bulb. That seems a very definite fact; but look at the action in the other bulb. I bring the candle, or a hot glass rod, near the other bar of pith, and it is strongly *repelled* by it, much more strongly than it was attracted in the first instance.

Here, again, is a third fact. I bring a piece of ice near the pith-bar which has just been repelled by the hot rod, and it is attracted, and follows the rod round as a magnetic needle follows a piece of iron.

The repulsion by radiation is the key-note of these researches. The movement of a small bar of pith is not very distinct, except to those near, and I wish to make this repulsion evident to all. I have therefore arranged a piece of apparatus by which it can be seen by all present. I will, by means of the electric light, project an image of a pendulum suspended *in vacuo* on the screen. You see that the approach of a candle gives the bob a veritable push, and, by alternately obscuring and uncovering the light, I can make the pendulum beat time to my movements.

What, then, is the cause of the contradictory action in these two bulbs—attraction in one, and repulsion in the other? It can be explained in a few words. Attraction takes place when air is present, and repulsion when air is absent.

Neutrality, or no movement, is produced when the vacuum is insufficient. A minute trace of air in the apparatus interferes most materially with the repulsion, and for a long time I was unaware of the powerful action produced by radiation in a "perfect" vacuum.

It is not at first sight obvious how ice or a cold body can produce the opposite effect to heat. The law of exchanges, however, explains this

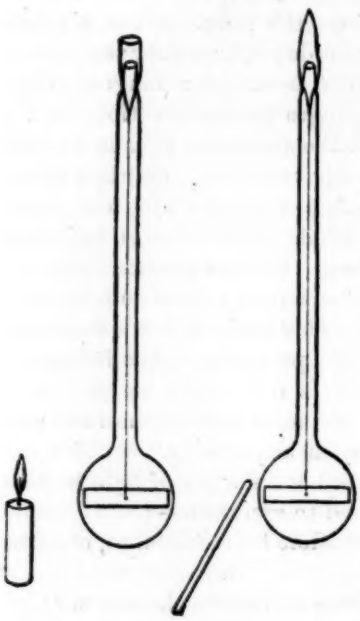

Fig. 1.

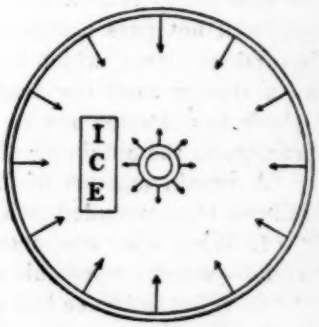

Fig. 2.

perfectly. The pith-bar and the whole of the surrounding bodies are incessantly exchanging heat-rays; and under ordinary circumstances the income and expenditure of heat are in equilibrium. Let me draw your attention to the diagram (Fig. 2), illustrating what takes place when I bring a piece of ice near the apparatus. The centre circle represents my piece of pith; the arrows show the influx and efflux of heat. A piece of ice brought near cuts off the influx of heat from one side, and therefore allows an excess of heat to fall on the pith from the opposite side. Attraction by a cold body is therefore seen to be only repulsion by the radiation from the opposite side of the room.

The later developments of this research have demanded the utmost refinement of apparatus. Everything has to be conducted in glass vessels, and these must be blown together till they make one piece, for none but fused joints are admissible. In an investigation depending for its successful prosecution on manipulative dexterity, I have been fortunate in having the assistance of my friend Mr. Charles Gimingham. All the apparatus you see before you are the fruits of his skillful manipulation, and I now want to draw your attention to

what I think is a masterpiece of glass-working—the pump which enables me so readily to produce a vacuum unattainable by ordinary means.

The pump here at work is a modification of the Sprengel pump, but it contains two or three valuable improvements. I cannot attempt to describe the whole of the arrangements, but I will rapidly run over them as illuminated by the electric light. It has a triple-fall tube in which the mercury is carried down, thus exhausting with threefold rapidity; it has Dr. McLeod's beautiful arrangement for measuring the residual gas; it has gauges in all directions, and a small radiometer attached to it to tell the amount of exhaustion that I get in any experiments; it has a contrivance for admitting oil of vitriol into the tubes without interfering with the progress of the exhaustion, and it is provided with a whole series of most ingenious vacuum-taps devised by Mr. Gimingham. The exhaustion produced in this pump is such that a current of electricity from an induction-coil will not pass across the vacuum. This pump is now exhausting a torsion-balance, which will be described presently. Another pump, of a similar kind but less complicated, is exhausting an apparatus which has enabled me to pass from the mere exhibition of the phenomena to the obtaining of quantitative measurements.

A certain amount of force is exerted when a ray of light or heat falls on the suspended pith, and I wished to ascertain—

1. What were the actual rays—invisible heat, luminous, or ultra-violet—which caused this action?

2. What influence had the color of the surface on the action?

3. Was the amount of action in direct proportion to the amount of radiation?

4. What was the amount of force exerted by radiation?

I required an apparatus which would be easily moved by the impact of light on it, but which would readily return to zero, so that measurements might be obtained of the force exerted when different amounts of light acted on it. At first I made an apparatus on the principle of Zöllner's horizontal pendulum. For a reason that will be explained presently, I am unable to show you the apparatus at work, but the principle of it is shown in the diagram (Fig. 3). The pendulum represented by this horizontal line has a weight at the end. It is supported on two fibres of glass, one stretched upward and the other stretched downward, both firmly fastened at the ends, and also attached to the horizontal rod (as shown in the figure) at points near together, but not quite opposite to one another.

It is evident that if there is a certain amount of pull upon each of these fibres, and that the pull can be so adjusted as to counteract the weight at the end and keep it horizontal, the nearer the beam approaches the horizontal line the slower its rate of oscillation. If I relax the tension, by throwing the horizontal beam downward, I get a

more rapid oscillation sideways. If I turn the leveling-screw so as to raise the beam and weight, the nearer it approaches the horizontal position the slower the oscillation becomes, and the more delicate is the instrument. Here is the actual apparatus that I tried to work with. The weight at the end is a piece of pith; in the centre is a glass mirror, on which to throw a ray of light, so as to enable me to see the movements by a luminous index. The instrument, inclosed in glass and exhausted of air, was mounted on a stand with leveling-screws, and with it I tried the action of a ray of light falling on the pith. I found that I could get any amount of sensitiveness that I liked; but it was not only sensitive to the impact of a ray of light, it was immeasurably more so to a change of horizontality. It was, in fact, too delicate for me to work with. The slightest elevation of one end of the instrument altered the sensitiveness, or the position of the

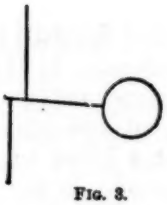

FIG. 3.

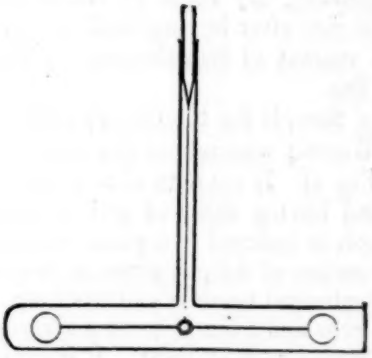

FIG. 4.

zero-point, to such a degree that it was impossible to try any experiments with it in such a place as London. A person stepping from one room to another altered the position of the centre of gravity of the house. If I walked from one side of my own laboratory to the other, I tilted the house over sufficiently to upset the equilibrium of the apparatus. Children playing in the street disturbed it. Prof. Rood, who has worked with an apparatus of this kind in America, finds that an elevation of its side equal to $\frac{1}{8000000}$ part of an inch is sufficient to be shown on the instrument. It was therefore out of the question to use an instrument of this construction, so I tried another form (shown in Fig. 4), in which a fine glass beam, having disks of pith at each end, is suspended horizontally by a fine glass fibre, the whole being sealed up in glass and perfectly exhausted. To the centre of oscillation a glass mirror is attached.

Now, a glass fibre has the property of always coming back to zero when it is twisted out of its position. It is almost, if not quite, a perfectly elastic body. I will show this by a simple experiment. This is a long glass fibre hanging vertically, and having an horizontal bar

suspended on it. I hold the bar, and turn it half round; it swings backward and forward for a few times, but it quickly comes back to its original position. However much twist, however much torsion, may be put on this, it always returns ultimately to the same position. I have twisted glass fibres round and kept them in a permanent state of twist more than a hundred complete revolutions, and they always came back accurately to zero. The principle of an instrument that I shall describe farther on depends entirely on this property of glass.

Instead of using silk to suspend the torsion-beam with, I employ a fibre of glass, drawn out very fine before the blow-pipe. A thread of glass of less than the thousandth of an inch in thickness is wonderfully strong, of great stiffness, and of perfect elasticity, so that, however much it is twisted round short of the breaking-point, it untwists itself perfectly when liberated. The advantage of using glass fibres for suspending my beam is, therefore, that it always returns accurately to zero after having tried an experiment, while I can get any desired amount of sensitiveness by drawing out the glass fibre sufficiently fine.

Here, then, is the torsion apparatus sealed on to a Sprengel pump. You will easily understand the construction by reference to the diagram (Fig. 4). It consists of an horizontal beam suspended by a glass fibre, and having disks of pith at each end coated with lampblack. The whole is inclosed in a glass case, made of tubes blown together, and by means of the pump the air is entirely removed. In the centre of the horizontal beam is a silvered mirror, and a ray from the electric light is reflected from it on to a scale in front, where it is visible as a small circular spot of light. It is evident that an angular movement of the torsion-beam will cause the spot of light to move to the right or to the left along the scale. I will first show you the wonderful sensitiveness of the apparatus. I simply place my finger near the pith-disk at one end, and the warmth is quite sufficient to drive the spot of light several inches along the scale. It has now returned to zero, and I place a candle near it. The spot of light flies off the scale. I now bring the candle near it alternately from one side to the other, and you see how perfectly it obeys the force of the candle. I think the movement is almost better seen without the screen than with it. The fog, which has been so great a detriment to every one else, is rather in my favor, for it shows the luminous index like a solid bar of light swaying to and fro across the room. The warmth of my finger, or the radiation from a candle, is therefore seen to drive the pith-disk away. Here is a lump of ice, and on bringing it near one of the disks the luminous index promptly shows a movement of apparent attraction.

With this apparatus I have tried many experiments, and among others I endeavored to answer the question, "Is it light, or is it heat, that produces the movement?"—for that is a question that is asked

me by almost every one; and a good many appear to think that, if the motion can be explained by an action of heat, all the novelty and the importance of the discovery vanish. Now, this question of light or heat is one I cannot answer, and I think that when I have explained the reason you will agree with me that it is unanswerable. There is no physical difference between light and heat. Here is a diagram of the visible spectrum (Fig. 5). The spectrum, as scientific

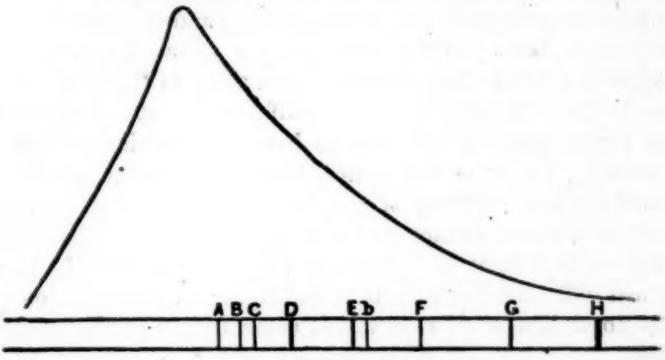

FIG. 5.

men understand it, extends from an indefinite distance beyond the red to an indefinite distance beyond the violet. We do not know how far it would extend one way or the other if no absorbing media were present; but, by what we may call a physiological accident, the human eye is sensitive to a portion of the spectrum situated between the line *A* in the red to about the line *H* in the violet. But this is not a physical difference between the luminous and non-luminous parts of the spectrum; it is only a physiological difference. Now, the part at the red end of the spectrum possesses, in the greatest degree, the property of causing the sensation of warmth, and of dilating the mercury in a thermometer, and of doing other things which are conveniently classed among the effects of *heat;* the centre part affects the eye, and is therefore called *light;* while the part at the other end of the spectrum has the greatest energy in producing *chemical action.* But it must not be forgotten that any ray of the spectrum, from whatever part it is selected, will produce all these physical actions in more or less degree. A ray here, at the letter *C* for instance in the orange, if concentrated on the bulb of a thermometer, will cause the mercury to dilate, and thus show the presence of *heat;* if concentrated on my hand I feel *warmth;* if I throw it on the face of a thermo-pile it will produce a current of *electricity;* if I throw it upon a sensitive photographic plate it will produce *chemical action;* and if I throw it upon the instrument I have just described it will produce *motion.* What, then, am I to call that ray? Is it light, heat, electricity, chemical action, or motion? It is neither. All these actions are inseparable

attributes of the ray of that particular wave-length, and are not evidences of separate identities. I can no more split that ray up into five or six different rays, each having different properties, than I can split up the element iron, for instance, into other elements, one possessing the specific gravity of iron, another its magnetic properties, a third its chemical properties, a fourth its conducting power for heat, and so on. A ray of light of a definite refrangibility is one and indivisible, just as an element is, and these different properties of the ray are mere functions of that refrangibility, and inseparable from it. Therefore when I tell you that a ray in the ultra-red pushes the instrument with a force of one hundred, and a ray in the most luminous part has a dynamic value of about half that, it must be understood that the latter action is not due to heat-rays which accompany the luminous rays, but that the action is one purely due to the wave-length and the refrangibility of the ray employed. You now understand why it is that I cannot give a definite answer to the question, "Is it heat or is it light that produces these movements?" There is no physical difference between heat and light; so, to avoid confusion, I call the total bundle of rays which come from a candle or the sun, *radiation*.

I found, by throwing the pure rays of the spectrum one after the other upon this apparatus, that I could obtain a very definite answer to my first question, "What are the actual rays which cause this action?"

The apparatus was fitted up in a room specially devoted to it, and was protected on all sides, except where the rays of light had to pass, with cotton-wool and large bottles of water. A heliostat reflected a beam of sunlight in a constant direction, and it was received on an appropriate arrangement of slit, lenses, prisms, etc., for projecting a pure spectrum. Results were obtained in the months of July, August, and September; and they are given in the figure (Fig. 5) graphically as a curve, the maximum being in the ultra-red and the minimum in the ultra-violet. Taking the maximum at 100, the following are the mechanical values of the different colors of the spectrum:

Ultra-red	100
Extreme red	85
Red	73
Orange	66
Yellow	57
Green	41
Blue	22
Indigo	8½
Violet	6
Ultra-violet	5

A comparison of these figures is a sufficient proof that the mechanical action of radiation is as much a function of the luminous rays as it is of the dark heat-rays.

The second question—namely, "What influence has the color of the surface on the action?" has also been solved by this apparatus.

In order to obtain comparative results between disks of pith coated with lampblack and with other substances, another torsion apparatus was constructed, in which six disks *in vacuo* could be exposed one after the other to a standard light. One disk always being lampblacked pith, the other disks could be changed so as to get comparisons of action. Calling the action of radiation from a candle on the lampblacked disk 100, the following are the proportions obtained:

Lampblacked pith	100
Iodide of palladium	87.3
Precipitated silver	56
Amorphous phosphorus	40
Sulphate of baryta	37
Milk of sulphur	31
Red oxide of iron	28
Scarlet iodide of mercury and copper	22
Lampblacked silver	18
White pith	18
Carbonate of lead	13
Rock-salt	6.5
Glass	6.5

This table gives important information on many points: one more especially—the action of radiation on lampblacked pith is five and a half times what it is on plain pith. A bar like those used in my first experiment, having one-half black and one-half white, exposed to a broad beam of radiation, will be pushed with five and a half times more strength on the black than on the white half, and if freely suspended will set at an angle greater or less according to the intensity of the radiation falling on it.

This suggests the employment of such a bar as a photometer, and I have accordingly made an instrument on this principle; its construction is shown in the diagram (Fig. 6). It consists of a flat bar of pith, *A*, half black and half white, suspended horizontally in a bulb by means of a long silk fibre. A reflecting mirror, *B*, and small magnet, *C*, are fastened to the pith, and a controlling magnet, *D*, is fastened outside so that it can slide up and down the tube, and thus increase or diminish sensitiveness. The whole is completely exhausted and then inclosed in a box lined with black velvet, with apertures for the rays of light to pass in and out. A ray of light from a lamp, *F*, reflected from the mirror, *B*, to a graduated scale, *G*, shows the movements of the pith-bar.

The instrument fitted up for a photometric experiment is in front of me on the table. A beam from the electric light falls on the little mirror, and is thence reflected back to the screen, where it forms a spot of light, the displacement of which to the right or the left shows the movement of the pith-bar. One end of the bar is blacked on

each side, the other end being left plain. I have two candles, *E E*, each twelve inches off the pith-bar, one on each side of it. When I remove the screens, *H H*, the candle on one side will give the pith a

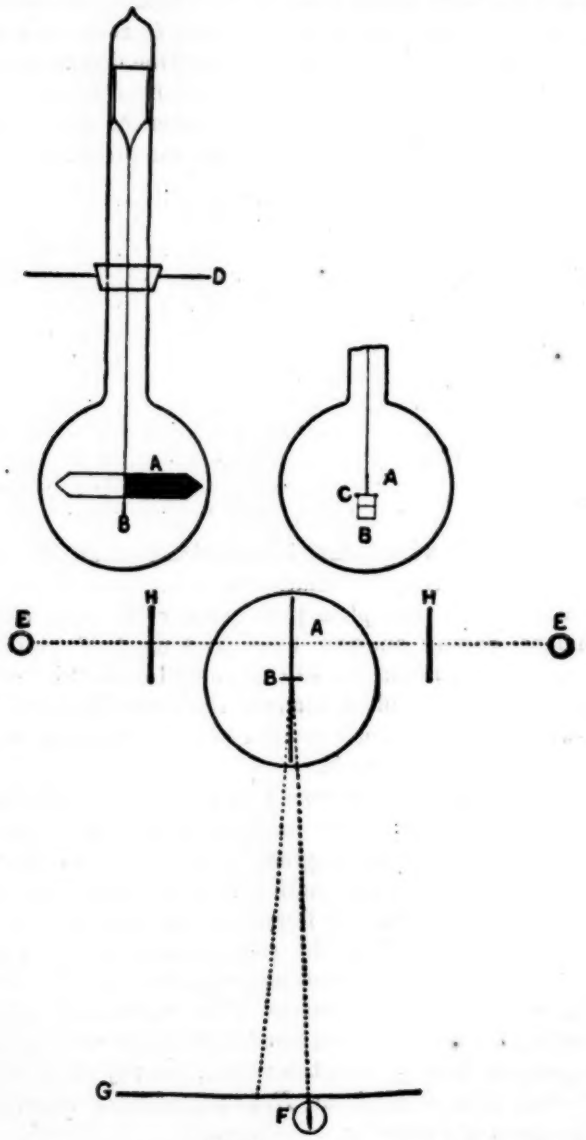

FIG. 6.

push in one direction, and the candle on the other side will give the pith a push in the opposite direction, and as they are the same distance off they will neutralize each other, and the spot of light will not move. I now take the two screens away: each candle is pushing the

pith equally in opposite directions, and the luminous index remains at zero. When, however, I cut one candle off, the candle on the opposite side exerts its full influence, and the index flies to one end of the scale. I cut the other one off and obscure the first, and the spot of light flies to the other side. I obscure them both, and the index comes quickly to zero. I remove the screens simultaneously, and the index does not move.

I will retain one candle 12 inches off, and put two candles on the other side 17 inches off. On removing the screens you see the index does not move from zero. Now the square of 12 is 144, and the square of 17 is 289. Twice 144 is 288. The light of these candles, therefore, is as 288 to 289. They therefore balance each other as nearly as possible. Similarly I can balance a gaslight against a candle. I have a small gas-burner here, which I place 28 inches off on one side, and you see it balances the candle 12 inches off. These experiments show how conveniently and accurately this instrument can be used as a photometer. By balancing a standard candle on one side against any source of light on the other, the value of the latter in terms of a candle is readily shown; thus in the last experiment the standard candle 12 inches off is balanced by a gas-flame 28 inches off. The lights are, therefore, in the proportion of 12^2 to 28^2, or as 1 to 5.4. The gas-burner is, therefore, equal to about five and a half candles.

In practical work on photometry it is often required to ascertain the value of gas. Gas is spoken of commercially as of so many candle-power. There is a certain "standard" candle which is supposed to be made invariable by act of Parliament. I have worked a great deal with these standard candles, and I find them to be among the most variable things in the world. They never burn with the same luminosity from one hour to the other, and no two candles are alike. I can now, however, easily get over this difficulty. I place a "standard" candle at such a distance from the apparatus that it gives a deflection of 100° on the scale. If it is poorer than the standard, I bring it nearer; if better, I put it farther off. Indeed, any candle may be taken; and if it be placed at such a distance from the apparatus that it will give a uniform deflection, say, of 100 divisions, the standard can be reproduced at any subsequent time; and the burning of the candle may be tested during the photometric experiments by taking the deflection it causes from time to time, and altering its distance, if needed, to keep the deflection at 100 divisions. The gaslight to be tested is placed at such a distance on the opposite side of the pith-bar that it exactly balances the candle. Then, by squaring the distances, I get the exact proportion between the gas and the candle.

Before this instrument can be used as a photometer or light-measurer, means must be taken to cut off from it all those rays coming from the candle or gas which are not actually luminous. A reference

to the spectrum diagram (Fig. 5) will show that at each end of the colored rays there is a large space inactive, as far as the eye is concerned, but active in respect to the production of motion—strongly so at the red end, less strong at the violet end. Before the instrument can be used to measure luminosity, these rays must be cut off. We buy gas for the light that it gives, not for the heat that it evolves on burning, and it would therefore never do to measure the heat and pay for it as light.

It has been found that a clear plate of alum, while letting all the light through, is almost if not quite opaque to the heating rays below the red. A solution of alum in water is almost as effective as a crystal of alum; if, therefore, I place in front of the instrument glass cells containing an aqueous solution of alum, the dark heat-rays are filtered off.

But the ultra-violet rays still pass through, and to cut these off I dissolve in the alum-solution a quantity of sulphate of quinine. This body has the property of cutting off the ultra-violet rays from a point between the lines *G* and *H*. A combination of alum and sulphate of quinine, therefore, limits the action to those rays which affect the human eye, and the instrument, such as you see it before you, becomes a true photometer.

This instrument, when its sensitiveness is not deadened by the powerful control magnet I am obliged to keep near it for these experiments, is wonderfully sensible to light. In my own laboratory, a candle thirty-six feet off produces a decided movement, and the motion of the index increases inversely with the square of the distance, thus answering the third question, "Is the amount of action in direct proportion to the amount of radiation?"

The experimental observations and the numbers which are required by the theoretical diminution of light with the square of the distance are sufficiently close, as the following figures show:

Candle	6	feet off	gives a deflection of	218·0°
"	12	"	"	54.0°
"	18	"	"	24.5°
"	24	"	"	13.0°
"	10	"	"	77.0°
"	20	"	"	19.0°
"	30	"	"	8.5°

The effect of two candles side by side is practically double, and of three candles three times that of one candle.

In the instrument just described, the candle acts on a pith-bar, one end of which is blacked on each side. But suppose I black the bar on alternate halves, and place a light near it sufficiently strong to drive the bar half round. The light will now have presented to it another black surface in the same position as the first, and the bar will be again driven in the same direction half round. This action will

be again repeated, the differential action of the light on the black and white surfaces keeps the bar moving, and the result will be rotation.

Here is such a pith-bar, blacked on alternate sides, and suspended in an exhausted glass bulb (Fig. 7). I project its image on the screen, and the strong light which shines on it sets it rotating with considerable velocity. Now it is slackening speed, and now it has stopped altogether. The bar is supported on a fibre of silk, which has twisted round till the rotation is stopped by the accumulated torsion. I put a water-screen between the bar and the electric light to cut off some of the active rays, and the silk untwists, turning the bar in the opposite direction. I now remove the water, and the bar revolves rapidly as at first.

FIG. 7.

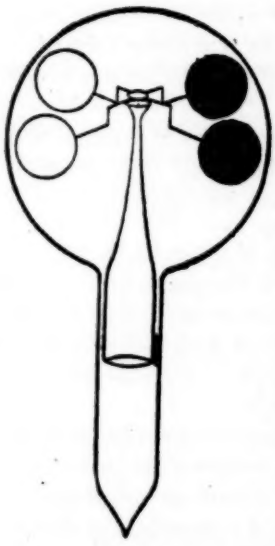

FIG. 8.

From suspending the pith on a silk fibre to balancing it on a point the transition is slight; the interfering action of torsion is thereby removed, and the instrument rotates continuously under the influence of radiation. Many of these little pieces of apparatus, to which I have given the name of radiometers, are on the table, revolving with more or less speed. The diagram (Fig. 8) shows their construction, which is very simple. They are formed of four arms of very fine glass, supported in the centre by a needle-point, and having at the extremities thin disks of pith lampblacked on one side, the black surfaces all facing the same way. The needle stands in a glass cup, and the arms and disks are delicately balanced so as to revolve with the slightest impetus.

Here are some rotating by the light of a candle. This one is now rather an historical instrument, being the first one in which I saw rotation. It goes very slowly in comparison with the others, but it is not bad for the first instrument of the sort that was ever made.

I will now, by means of a vertical lantern, throw on the screen the projection of one of these instruments, so as to show the movement rather better than you could see it on the table. The electric light falling vertically downward on it, and much of the power being cut off by water and alum screens, the rotation is slow. I bring a candle

near and the speed increases. I now lift the radiometer up, and place it full in the electric light, projecting its image direct on the screen, and it goes so rapidly that if I had not cut out the four pieces of pith of different shapes you would have been unable to follow the movement.

The speed with which a sensitive radiometer will revolve in the sun is almost incredible; and the electric light, such as I have it in this lantern, cannot be far short of full sunshine. Here is the most sensitive instrument I have yet made, and I project its image on the screen, letting the full blaze of the electric light shine upon it. Nothing is seen but an undefined nebulous ring, which becomes at times almost invisible. The number of revolutions per second cannot be counted, but they must be several hundreds, for one candle has made it spin round forty times a second.

I have called the instrument the radiometer because it will enable me to measure the intensity of radiation falling on it by counting the revolutions in a given time; the law being that the rapidity of revolution is inversely as the square of the distance between the light and the instrument.

When exposed to different numbers of candles at the same distance off, the speed of revolution in a given time is in proportion to the number of candles; two candles giving twice the rapidity of one candle, and three, three times, etc.

The position of the light in the horizontal plane of the instrument is of no consequence, provided the distance is not altered; thus two candles, one foot off, give the same number of revolutions per second, whether they are side by side or opposite to each other. From this it follows that if the radiometer is brought into a uniformly lighted space it will continue to revolve.

It is easy to get rotation in a radiometer without having the surfaces of the disks differently colored. Here is one having the pith-disks blacked on both sides. I project its image on the screen, and there is no movement. I bring a candle near it, and shade the light from one side, when rapid rotation is produced, which is at once altered in direction by moving the shade to the other side.

I have arranged here a radiometer so that it can be made to move by a very faint light, and at the same time its rotation is easily followed by all present. In this bulb is a large six-armed radiometer carrying a mirror in its centre. The mirror is almost horizontal, but not quite so, and therefore, when I throw a beam of electric light vertically downward on to the central mirror, the light is reflected off at a slight angle, and, as the instrument rotates, its movement is shown by the spot of light traveling round the ceiling in a circle. Here again the fog helps us, for it gives us an imponderable beam of light moving round the room like a solid body, and saving you the trouble of looking up at the ceiling. I now set the radiometer moving round by the light of a candle, and I want to show you that colored light

does not very much interfere with the movement. I place yellow glass in front, and the movement is scarcely diminished at all. Very deep-colored glass, you see, diminishes it a little more. Blue and green glass make it go a little slower, but still do not diminish the speed one-half. I now place a screen of water in front: the instrument moves with diminished velocity, rotating with about one-fourth its original speed.

Taking the action produced by a candle-flame as	100
Yellow glass reduces it to	89
Red " " "	71
Blue " " "	56
Green " " "	56
Water " "	26
Alum " "	15

I now move the candle a little distance off, so as to make the instrument move slower, and bring a flask of boiling water close to it. See what happens. The luminous index no longer moves steadily, but in jerks. Each disk appears to come up to the boiling water with difficulty, and to hurry past it. More and more sluggishly do they move past, until now one has failed to get by, and the luminous beam, after oscillating to and fro a few times, comes to rest. I now gradually bring the candle near. The index shows no movement. Nearer still. There is now a commencement of motion, as if the radiometer were trying to push past the resistance offered by the hot water; but it is not until I have brought the candle to within a few inches of the glass globe that rotation is recommenced. On these pith radiometers the action of dark heat is to repel the black and white surfaces almost equally, and this repulsion is so energetic as to overcome the rotation caused by the candle, and to stop the instrument.

With a radiometer constructed of a good conductor of heat, such as metal, the action of dark heat is different. Here is one made of silvered copper, polished on one side and lampblacked on the other. I have set it moving with a candle slightly the normal way. Here is a glass shade heated so that it feels decidedly warm to the hand. I cover the radiometer with it, and the rotation first stops, and then recommences the reverse way. On removing the hot shade the reverse movement ceases and normal rotation recommences.

If, however, I place a hot glass shade over a pith radiometer, the arms at once revolve the normal way, as if I had exposed the instrument to light. The diametrically opposite behavior of a pith and a metal instrument when exposed to the dark heat radiated from a hot glass shade is very striking. The explanation of the action is not easy, but it depends on the fact that the metal is one of the best conductors of heat, while pith is one of the worst.

One more experiment with this metallic radiometer. I heat it strongly with a spirit-lamp, and the arms spin round rapidly. Now

the whole bulb is hot, and I remove the lamp: see what happens. The rotation quickly diminishes. Now it is at rest; and now it is spinning round just as fast the reverse way. I can produce this reverse movement only with difficulty with a pith instrument. The action is due to the metal being a good conductor of heat. As it absorbs heat it moves one way; as it radiates heat it moves the opposite way.

At first I made these instruments of the very lightest material possible, some of them not weighing more than half a grain; and, where extreme sensitiveness is required, lightness is essential. But the force which carries them round is quite strong enough to move a much greater weight. Thus the metallic instrument I have just experimented with weighs over thirteen grains, and here is one still heavier, made of four pieces of looking-glass blacked on the silvered side, which are quickly sent round by the impact of this imponderable agent, and flash the rays of light all round the room when the electric lamp is turned on the instrument.

Before dismissing this instrument let me show one more experiment. I place the looking-glass and the metal radiometer side by side, and, screening the light from them, they come almost to rest. Their temperature is the same as that of the room. What will happen if I suddenly chill them? I pour a few drops of ether on each of the bulbs. Both instruments begin to revolve. But notice the difference. While the movement in the case of the metal radiometer is direct, that of the looking-glass instrument is reverse. And yet to a candle they both rotate the same way, the black being repelled.

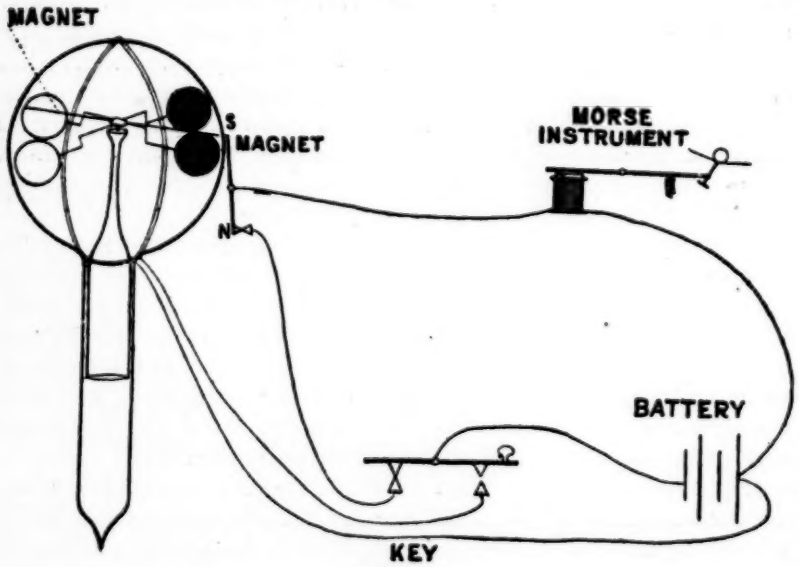

FIG. 9.

Now, having found that this force would carry round a comparatively heavy weight, another useful application suggested itself. If I can carry round heavy mirrors or plates of copper, I can carry round a magnet. Here, then (Fig. 9), is an instrument carrying a magnet, and outside is a smaller magnet, delicately balanced in a vertical position, having the south pole at the top and the north pole at the bottom. As the inside magnet comes round, the outside magnet, being delicately suspended on its centre, bows backward and forward, and, making contact at the bottom, carries an electric current from a battery to a Morse instrument. A ribbon of paper is drawn through the "Morse" by clock-work, and at each contact—at each revolution of the radiometer—a record is printed on the strip of paper by dots; close together if the radiometer revolves quickly, farther apart if it goes slower.

Here the inner magnet is too strong to allow the radiometer to start with a faint light without some initial impetus. Imagine the instrument to be on the top of a mountain, away from everybody, and I wish to start it in the morning. Outside the bulb are a few coils of insulated copper wire, and by depressing the key for an instant I pass an electric current from the battery through them. The interior magnet is immediately deflected from its north-south position, and the impetus thus gained enables the light to keep up the rotation. In a proper meteorological instrument I should have an astatic combination inside the bulb, so that a very faint light would be sufficient to start it, but in this case I am obliged to set it going by an electric current. I have placed a candle near the magnetic radiometer. I now touch the key; the instrument immediately responds; the paper

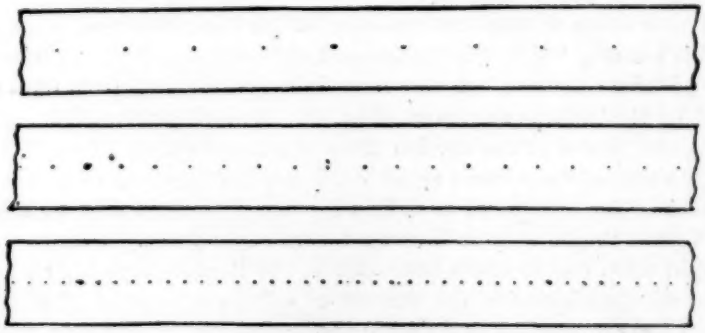

FIG. 10.

unwinds from the Morse instrument, and on it you will see dots in regular order. I put the candle eight inches off, and the dots come wide apart. I place it five and three-quarters inches off, and two dots come where one did before. I bring the candle four inches from the instrument, and the dots become four times as numerous (Fig. 10), thus recording automatically the intensity of the light falling on the

instrument, and proving that in this case also the radiometer obeys the law of inverse squares.

This instrument, the principle of which I have illustrated to-night, is not a mere toy or scientific curiosity, but it is capable of giving much useful information in climatology. You are well aware that the temperature, the rainfall, the atmospheric pressure, the direction and force of the wind, are now carefully studied in most countries, in order to elucidate their sanitary condition, their animal and vegetable productions, and their agricultural capabilities. But one most important element, the amount of light received at any given place, has been hitherto but very crudely and approximately estimated, or rather guessed at. Yet it cannot be denied that sunlight has its effect upon life and health, vegetable, animal, and human, and that its relative amount at any place is hence a point of no small moment. The difficulty is now overcome by such an instrument as this. The radiometer may be permanently placed on some tall building, or high mountain, and, by connecting it by telegraphic wires to a central observatory, an exact account can be kept of the proportion of sunlight received in different latitudes, and at various heights above the sea-level. Furthermore, our records of the comparative temperature of different places have been hitherto deficient. The temperature of a country depends partly on the amount of rays which it receives direct from the sun, and partly on the atmospheric and oceanic currents, warm or cold, which sweep over or near it. The thermometer does not discriminate between these influences; but the radiometer will enable us now to distinguish how much of the annual temperature of a place is due to the direct influence of the sun alone, and how much to the other factors above referred to.

I now come to the last question which I stated at the beginning of this lecture, "What is the amount of force exerted by radiation?" Well, I can calculate out the force in a certain way, from data supplied by this torsion apparatus (Fig. 4). Knowing the weight of the beam, the power of the torsion fibre of glass, its time of oscillation, and the size of the surface acted on, it is not difficult to calculate the amount of force required to deflect the beam through a given angle; but I want to get a more direct measure of the force. I throw a ray of light upon one of these instruments, and it gives a push; surely it is possible to measure the amount of this push in parts of a grain. This I have succeeded in doing in the instrument behind me; but before showing the experiment I want to illustrate the principle upon which it depends. Here is a very fine glass fibre suspended from an horizontal bar, and I wish to show you the strength of it. The fibre is only a few thousandths of an inch thick; it is about three feet long, and at the lower end is hanging a scale-pan, weighing 100 grains. So I start with a pull of 100 grains on it. I now add little lead weights, 50 grains each, till it breaks. It bears a pull of 750 grains,

but gives way when additional weight is added. You see, then, the great strength of a fibre of glass, so fine as to be invisible to all who are not close to it, to resist a tensile strain.

Now I will illustrate another equally important property of a glass thread, viz., its power to resist torsion. Here is a a still finer glass thread, stretched horizontally between two supports; and in order to show its position I have put little jockeys of paper on it. One end is cemented firmly to a wooden block, and the other end is attached to a little instrument called a counter—a little machine for registering the number of revolutions. I now turn this handle till the fibre breaks, and the counter will tell me how many twists I have given this fibre of glass. You see it breaks at twenty revolutions. This is rather a thicker fibre than usual. I have had them bear more than 200 turns without breaking, and some that I have worked with are so fine that if I hold one of them by the end it curls itself up and floats about the room like a piece of spider's thread.

Having now illustrated these properties of glass fibres, I will try to show a very delicate experiment. I want to ascertain the amount of pressure which radiation exerts on a blackened surface. I will put a ray of light on the pan of a balance, and give you its weight in grains, for I think in this Institution and before this audience I may be allowed a scientific use of the imagination, and may speak of weighing that which is not affected by gravitation.

The principle of the instrument is that of W. Ritchie's torsion balance, described by him in the "Philosophical Transactions" for 1830. The construction is somewhat complicated, but it can be made out on reference to the diagram (Fig. 11). A light beam, *A B*, having two square inches of pith, *C*, at one end, is balanced on a very fine fibre of glass, *D D'*, stretched horizontally in a tube; one end of the fibre being connected with a torsion handle, *E*, passing through the tube, and indicating angular movements on a graduated circle. The beam is cemented to the torsion fibre, and the whole is inclosed in glass, and connected with the mercury pump by a spiral tube, *F*, and exhausted as perfectly as possible. *G* is a spiral spring, to keep the fibre in a uniform state of tension. *H* is a piece of cocoon silk. *I* is a glass stopper, which is ground into the tube as perfectly as possible, and then highly polished and lubricated with melted India-rubber, which is the only substance I know that allows perfect lubrication and will still hold a vacuum. The pith, *C*, represents the scale-pan of the balance. The cross-beam *A B*, which carries it, is cemented firmly to the thin glass fibre, *D*, and in the centre is a piece of mirror, *K*. Now, the cross-beam *A B* and the fibre *D* being rigidly connected together, any twist which I give to the torsion handle *E* will throw the beam out of adjustment. If, on the other hand, I place a weight on the piece of pith *C*, that end of the beam will fall down, and I shall have to turn the handle, *E*, round and round a cer-

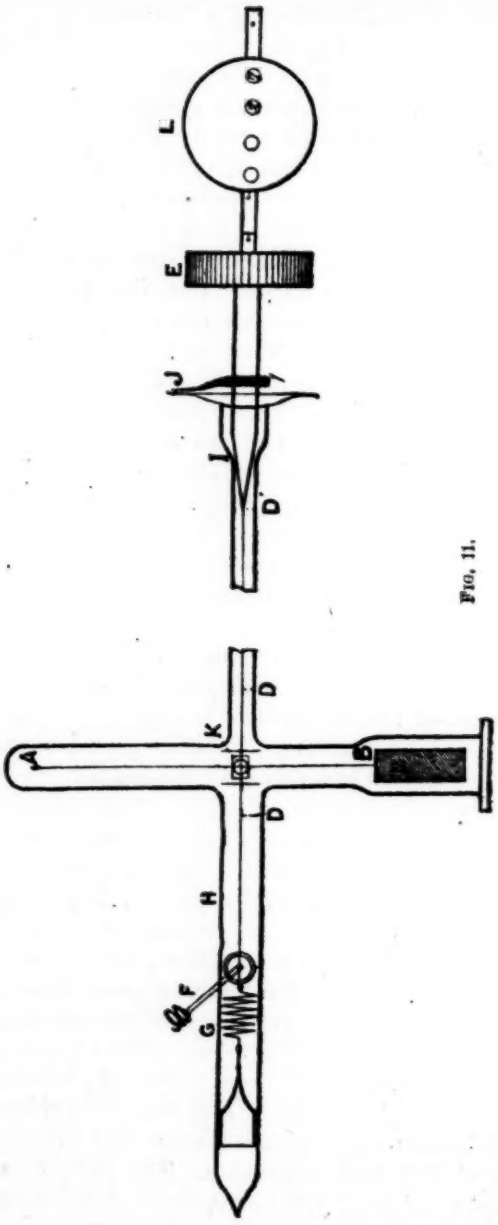

FIG. 11.

tain number of times, until I have put sufficient torsion on the fibre *D* to lift up the beam. Now, according to the law of torsion, the force with which a perfectly elastic body like glass tends to untwist itself is directly proportional to the number of degrees through which it has been twisted; therefore, knowing how many degrees of torsion I

must put on the fibre to lift up the $\frac{1}{100}$ of a grain weight, I can tell how many degrees of torsion are required to lift up any other weight; and conversely, putting an unknown weight or pressure on the pith, I can find its equivalent in grains by seeing how much torsion it is equal to. Thus, if $\frac{1}{100}$ of a grain requires 10,000° of torsion, $\frac{1}{50}$ of a grain would require 20,000°; and conversely, a weight which required 5,000° torsion would weigh $\frac{1}{200}$ of a grain. Once knowing the torsion equivalent of $\frac{1}{100}$ of a grain, the ratio of the known to the unknown weights is given by the degrees of torsion.

Having thus explained the working of the torsion balance I will proceed to the actual experiment. On the central mirror I throw a ray from the electric light, and the beam reflected on a particular spot of the ceiling will represent zero. The graduated circle *J* of the instrument also stands at zero, and the counter which I fasten on at the end *L* stands at *O*. The position of the spot of light reflected from the little concave mirror being noted, the torsion balance enables me to estimate the pressure or weight of a beam of light to a surprising degree of exactness. I lift up my little iron weight by means of a magnet (for working in a vacuum I am restricted in the means of manipulating), and drop it in the centre of the pith: it knocks the scale-pan down, as if I had placed a pound weight upon an ordinary balance, and the index-ray of light has flown far from the zero-point on the ceiling. I now put torsion on the fibre to bring the beam again into equilibrium. The index-ray is moving slowly back again. At last it is at zero, and on looking at the circle and counter I see that I have had to make 27 complete revolutions and 301°, or $27 \times 360° + 301° = 10{,}021°$, before the force of torsion would balance the $\frac{1}{100}$ of a grain.

I now remove the weight from the pith-pan of my balance, and liberate the glass thread from torsion by twisting it back again. Now the spot of light on the ceiling is at zero, and the counter and index are again at *O*.

Having thus obtained the value of the $\frac{1}{100}$ of a grain in torsion degrees, I will get the same for the radiation from a candle. I place a lighted candle exactly 6 inches from the blackened surface, and on removing the screen the pith scale-pan falls down, and the index-ray again flies across the ceiling. I now turn the torsion handle, and in much less time than in the former case the ray is brought back to zero. On looking at the counter I find it registers four revolutions, and the index points to 188°, making altogether $360° \times 4 + 188 = 1628°$, through which the torsion fibre has to be twisted to balance the light of the candle.

It is an easy calculation to convert this into parts of a grain weight; 10,021 torsion degrees representing 0.01 grain, 1628 torsion degrees represent 0.001624 grain.

10,021° : 0.01 grain :: 1628° : 0.001624 grain.

The radiation of a candle 6 inches off, therefore, weighs or presses the two square inches of blackened pith with a weight of 0.001624 grain. In my own laboratory, working with this torsion balance, I found that a candle 6 inches off gave a pressure of 0.001772 grain. The difference is only 0.000148 grain, and is fairly within the allowable limits of a lecture experiment. But this balance is capable of weighing to far greater accuracy than that. You have seen that a torsion of 10,021° balanced the hundredth of a grain. If I give the fibre 1° more twist the weight is overbalanced, as shown by the movement of the index-ray on the ceiling. Now 1° of torsion is about the $\frac{1}{10000}$ part of the whole torsion required by the $\frac{1}{100}$ grain. It represents, therefore, the $\frac{1}{10000}$ part of the $\frac{1}{100}$, or the millionth part of a grain.

Divide a grain-weight into a million parts, place one of them on the pan of the balance, and the beam will be instantly depressed!

Weighed in this balance the mechanical force of a candle 12 inches off was found to be 0.000444 grain; of a candle 6 inches off, 0.001772 grain. At half the distance the weight of radiation should be four times, or 0.001776 grain; the difference between theory and experiment being only four-millionths of a grain is a sufficient proof that the indications of this instrument, like those of the apparatus previously described, follow the law of inverse squares. An examination of the differences between the separate observations and the mean shows that my estimate of the sensitiveness of this balance is not excessive, and that in practice it will safely indicate the millionth of a grain.

I have only had one opportunity of getting an observation of the weight of sunlight: it was taken on December 13th, but the sun was so obscured by thin clouds and haze that it was only equal to 10.2 candles 6 inches off. Calculating from this datum, it is seen that the pressure of sunshine is 2.3 tons per square mile.

But, however fair an equivalent ten candles may be for a London sun in December, a midsummer sun in a cloudless sky has a very different value. Authorities differ as to its exact equivalent, but I underestimate it at 1,000 candles 12 inches off.

Let us see what pressure this will give: A candle 12 inches off, acting on 2 square inches of surface, was found equal to 0.000444 grain; the sun, equaling 1,000 candles, therefore gives a pressure of 0.444000 grain; that is equal to about 32 grains per square foot, to 2 cwts. per acre, 57 tons per square mile, or nearly 3,000,000,000 tons on the exposed surface of the globe—sufficient to knock the earth out of its orbit if it came upon it suddenly.

It may be said that a force like this must alter our ordinary ideas of gravitation; but it must be remembered that we only know the force of gravity as between bodies such as they actually exist, and we do not know what this force would be if the temperatures of the gravi-

tating masses were to undergo a change. If the sun is gradually cooling, possibly its attractive force is increasing, but the rate will be so slow that it will probably not be detected by our present means of research.

While showing this experiment I wish to have it distinctly understood that I do not attach the least importance to the actual numerical results. I simply wish to show you the marvelous sensitiveness of the apparatus with which I am accustomed to work. I may, indeed, say that I know these rough estimates to be incorrect. It must be remembered that our earth is not a lampblacked body inclosed in a glass case, nor is its shape such as to give the maximum of surface with the minimum of weight. The solar forces which perpetually pour on it are not simply absorbed and degraded into radiant heat, but are transformed into the various forms of motion we see around us, and into the countless forms of vegetable, animal, and human activity. The earth, it is true, is poised in vacuous space, but it is surrounded by a cushion of air; and, knowing how strongly a little air stops the movement of repulsion, it is easy to conceive that the sun's radiation through this atmospheric layer may not produce any important amount of repulsion. It is true the upper surface of our atmosphere must present a very cold front, and this might suffer repulsion by the sun; but I have said enough to show how utterly in the dark we are as to the cosmical bearings of this action of radiation, and further speculation would be but waste of time.

It may be of interest to compare these experimental results with a calculation made in 1873, before any knowledge of these facts had been made public.

Prof. Clerk Maxwell, in his "Electricity and Magnetism," vol. ii., p. 391, writes as follows: "The mean energy in one cubic foot of sunlight is about 0.0000000882 of a foot-pound, and the mean pressure on a square foot is 0.0000000882 of a pound-weight. A flat body exposed to sunlight would experience this pressure on its illuminated side only, and would therefore be repelled from the side on which the light falls."

Calculated out, this gives the pressure of sunlight equal to about two and a half pounds per square mile. Between the two and a half pounds deduced from calculation and the fifty-seven tons obtained from experiment the difference is great; but not greater than is often the case between theory and experiment.

In conclusion, I beg to call especial attention to one not unimportant lesson which may be gathered from this discovery. It will be at once seen that the whole springs from the investigation of an anomaly. Such a result is by no means singular. Anomalies may be regarded as the finger-posts along the high-road of research, pointing to the by-ways which lead to further discoveries. As scientific men are well aware, our way of accounting for any given phenomenon is not

always perfect. Some point is perhaps taken for granted, some peculiar circumstance is overlooked. Or else our explanation agrees with the facts not perfectly, but merely in an approximate manner, leaving a something still to be accounted for. Now, these residual phenomena, these very anomalies, may become the guides to new and important revelations.

In the course of my research anomalies have sprung up in every direction. I have felt like a traveler navigating some mighty river in an unexplored continent. I have seen to the right and the left other channels opening out, all claiming investigation, and promising rich rewards of discovery for the explorer who shall trace them to their source. Time has not allowed me to undertake the whole of a task so vast and so manifold. I have felt compelled to follow out, as far as lay in my power, my original idea, passing over reluctantly the collateral questions springing up on either hand. To these I must now invite the attention of my fellow-workers in science. There is ample room for many inquirers.

Nor must we forget that the more rigidly we scrutinize our received theories, our routine explanations and interpretations of Nature, and the more frankly we admit their shortcomings, the greater will be our ultimate reward. In the practical world fortunes have been realized from the careful examination of what has been ignorantly thrown aside as refuse; no less, in the sphere of science, are reputations to be made by the patient investigation of anomalies.—*Advance Sheets of Quarterly Journal of Science.*

THE CAUSES OF THE COLD OF THE ICE PERIOD.

By Prof. J. S. NEWBERRY,
of columbia college.

A FEW years ago the scientific world was startled by the assertion—made by Charpentier and Agassiz, who had been studying the glacial phenomena of Switzerland—that at no very remote period, geologically speaking, the climate of the northern hemisphere had been very much colder than at present; and that the arctic conditions which now prevail in Greenland—with perpetual snow-sheets, and glaciers reaching the sea—extended as far south as the middle of the present temperate zone.

At first, seriously questioned by most, strenuously denied by some, this theory was found to be sustained by such abundant and indisputable evidence—the inscriptions left by the glaciers themselves—that it was not long before it had secured a general acceptance from geologists. Since then there has been a vast amount of theorizing

and investigation, to determine if possible the causes of these remarkable changes of climate.

Up to the present time, however, no theory has been proposed which has been sustained by really satisfying evidence, and there is still much difference of opinion on the question among those who know most about it.

As the subject is one of peculiar geological significance, and great dramatic interest, I venture to bring forward some notes upon it, taken from the geologist's standpoint, hoping that they may contribute in some slight degree to the solution of the problem.

The theories which have been proposed to account for the cold of the Ice period divide themselves into two groups, viz., the cosmical and terrestrial; or those which invoke extraneous or astronomical influences, and those which look to changes in the earth itself, or on its surface, for a sufficient cause or causes.

In the first category may be enumerated the theory of Prof. Croll, that variations in the eccentricity of the earth's orbit have induced great alternations of climate on portions of the earth's surface; that of Belt and Drayson, which supposes the known variability of the angle of the pole with the ecliptic to have been at times sufficiently great to have brought arctic conditions locally down into the temperate zone; also, the speculations that the heat evolved from the sun has been variable in quantity, that the earth has at various times passed through cold spaces in the universe, etc.

In the second category are the views first put forth by Lyell, according to which all the variations of climate recorded in geological history have been induced by changes in the earth itself or on its surface.

In this paper I shall consider only the latter theory, leaving the discussion of the astronomical aspects of the subject to astronomers, mathematicians, and physicists, who alone are competent to thoroughly investigate them.

The explanation given by Lyell of the cold of the Ice period is in conformity with his characteristic conservatism. It is well known that the climatic conditions of all parts of the earth's surface are profoundly affected by their topographical features. This may be seen at a glance by reference to any map on which the isothermal lines are delineated. Continental surfaces are known to be productive of extremes of temperature, while the climate of sea areas is comparatively equable; and the general character of the climate of land and water surfaces is further and locally affected by the configuration and altitude of the land, by the breadth and depth of the oceanic basins, and especially by the ocean-currents. The sea forms the great evaporating surface, and the source from which is derived the enormous quantity of water transported by the system of atmospheric circulation. The local climate of continents is also largely influenced by the winds

which blow over them; for these determine, to a considerable degree, the temperature and the annual rainfall; hence the volume and excavating power of rivers, etc. The higher portions of continents, as mountain-chains and plateaux, are colder than the lowlands, and hence become condensers of moisture—places where snow accumulates and glaciers are formed.

A striking illustration of the influence of topography on climate is shown by the high mountains of the tropics, where perpetual snow and glaciers are coexistent with extreme tropical conditions, not only on the same parallel, but within a narrow area. It is evident, then, that topographical changes such as could be easily conceived would readily and perfectly accomplish all the alternations of climate of which we have any evidence in geological history. Recognizing the potency of topographical causes, Lyell sought for, and thought he had found, a sufficient explanation of the contrast between the climates of the Ice period and the present, in changes in the physical geography of the northern hemisphere; assuming and believing that the Glacial period was marked and caused by great elevation and breadth of land-surface about the pole, and, as a corollary and consequence of this proposition, a depression of land and a broadening of oceanic surfaces in the temperate and tropical zones.

This theory affords so simple an explanation of the problem of the Ice period, that it at first strongly commends itself to those who are most cautious and logical in their modes of thought and investigation. Modern science is eminently conservative, and one of the first lessons learned by the investigator of this age is, to exhaust all known causes of phenomena before appealing to the unknown. Still, however plausible this view may be, it must be sustained by solid and substantial proof before it deserves to be regarded as anything but a theory, and before it can be accepted as a rule of faith and practice among geologists. Unfortunately, such proof is not only yet wanting, but there are many facts which, in the light of our present knowledge, seem to indicate that it will never be obtained. The theory of Lyell has, however, been adopted by Prof. Dana, in the last edition of his "Manual," where he says (p. 541), "The occurrence of an Ice period was probably dependent mainly, as suggested by Lyell, on the extension and elevation of the land over the higher latitudes." Prof. Dana has further elaborated and applied the Lyellian hypothesis by suggesting that in the Glacial period barriers of land connected the continents of the two hemispheres, and excluded the tropical currents from the polar seas, in this way cutting off the most powerful equalizing influences, and inducing an exaggeration of the heat of the tropics and the cold of the polar regions. He also claims that high and broad land-surfaces in the circumpolar areas formed great condensers and refrigerators, upon which the moisture, freely and rapidly evaporated from the seething caldron of the circumscribed

tropical seas, was precipitated to form almost universal snow-fields and glaciers; certainly very favorable conditions for the production of many of the phenomena which characterized the Glacial period. It must be remembered, however, that this theory presupposes barriers established not only across the North Atlantic and Pacific Oceans, but in the southern hemisphere as well—for this also had its Ice period—barriers connecting the widely-separated promontories of Cape Horn, Cape of Good Hope, and the islands of the East Indian Archipelago; also that, simultaneously with the existence of such barriers, the tropical lands were depressed, and the sea spread its sediments over much of what is in the present age *terra firma*.

In reviewing the theory proposed by Lyell and Dana, I have been impressed with the conviction that if the physical geography of the northern and southern hemispheres had been either alternately or simultaneously such as this theory requires, we should find some evidence of it, apart from the inscriptions made by glaciers nearer the equator than any now exist. In the search for such evidence, however, I have not only failed to find it, but have, as it seems to me, found other things which go far to disprove the theory.

In order to fully state the case, it will be necessary to review several chapters in geological history, and compare the preceding and also the succeeding age with that in which the climate of Greenland came as far south as New York.

The results of such comparisons may be given as follows:

I. It is known to most students of geology that, during the Tertiary age, the climate of all the arctic regions was warm-temperate. A luxuriant forest then covered Greenland, and all the northern portion of this continent; such a forest as could only flourish in a climate as mild as that of our Middle and Southern States.[1]

According to the Lyellian hypothesis this should have been a period of great depression of arctic, and elevation of tropical lands; but we have proof that such was not the case. On the contrary, the land area at the north was broader then than now, while in the tropics it was narrower.

It can be shown, too, that land-connection then existed in northern latitudes between Europe and America, and also between America and Asia. The Atlantic bridge stretched from Greenland to Iceland, thence to the Hebrides and Scotland, which was then part of the

[1] It has been suggested that the warmth of the Tertiary climate was simply the effect of the residual heat of a globe cooling from incandescence, but many facts disprove this. For example, the fossil plants found in our Lower Cretaceous rocks in Central North America indicate a temperate climate in latitude 35° to 40° in the Cretaceous age. The coal-flora, too, and the beds of coal, indicate a moist, equable, and warm but not hot climate in the Carboniferous age, millions of years before the Tertiary, and 3,000 miles farther south than localities where magnolias, tulip-trees, and deciduous cypresses, grew in the latter age. Some learned and cautious geologists even assert that there have been several Ice periods, one as far back as the Devonian.

European Continent. The Pacific bridge was where Behring's Straits now are.

These conclusions are deducible from the following facts:

1. Our American flora, which began in the Cretaceous, spread in the Tertiary age to Europe on the one hand, and to China and Japan on the other; and this could only have taken place when the continents were connected. The characteristic plants of this flora have been found fossilized on the Upper Missouri, on Mackenzie's River, Disco Island, Greenland, Iceland, the island of Mull, and on the continent of Europe as far south as Italy. No collection has been made of Tertiary plants in Japan and China, but the living flora of these countries contains a large number of species identical with those found, either living or fossil, in North America. The remarkable similarity between the flora of Northeastern Asia and that of America, so clearly shown by Prof. Gray, is such as to demonstrate a community of origin, and that its place of origin was America may be fairly inferred from the character of the present American flora and from the facts that a large part of the most characteristic genera are found here in the Cretaceous rocks, and many of the living *species* in our fresh-water Tertiaries.

2. Marine Tertiary deposits are almost completely absent from the arctic lands, while they now skirt or cover most tropical continents and islands.

Rocks containing marine Tertiary fossils are conclusive evidence of the submergence in Tertiary times of the land in the localities where they occur; and they would not fail to exist over great areas in the arctic, had the land there been more depressed in the Tertiary age than now; since most of the country which borders the Arctic Sea, both in America and Asia, lies but little above the sea-level.

The Tertiary strata, that have yielded more than three hundred species of land-plants at the far north are generally fresh-water and marsh deposits, containing fresh-water shells and beds of lignite similar to those of the central portions of our own continent. In contrast to the state of things thus indicated, the marine Tertiaries, which form the margins of our South Atlantic and Gulf States, the West Indies, the Isthmus, and the northern part of South America, are automatic records of high sea or low land level, in the tropical regions during Tertiary times.

These facts seem to prove that in the period when a warm-temperate climate prevailed over all the arctic regions, the land was broader and higher than now at the north, lower and narrower at the south; and that barriers did then exist which excluded the tropical ocean-currents from the arctic sea.

II. Just what the topography of the arctic regions was during the Glacial period, we have as yet no very full and accurate information. It has been generally supposed that at least certain areas in the

north were then high, but this cannot be said to be proved. That the arctic lands have been at *some time* raised higher than now, is shown by the fiords of the northern coasts, which, as first pointed out by Dana, must have been excavated by subaërial erosion; but a large part of that erosion may have been effected in the Tertiary age, and perhaps it was chiefly accomplished then.

When a dense forest clothed the arctic lands, and spread over continuous land-surfaces to Europe and Asia, these now half-submerged fiords were valleys traversed by flowing streams; for the abundant Tertiary vegetation of the far north proves the country to have been well watered. That these fiords were filled with glaciers during the Ice period is certain, as the bottoms and sides of many of them are glaciated, but this would happen again with a depression of temperature, and without a depression of sea-level. The fact that the glaciated surface of the bottoms of fiords in Sweden and America passes under the sea, and reaches as far as observation can be carried, is not the proof of elevation it has been claimed to be, for the glaciers that now reach the sea must score their beds to the depth of several hundred feet, before their extremities are lifted up by the one-tenth greater gravity of water, and are floated off as icebergs.[1]

Prof. J. W. Dawson holds the view that the Glacial period was one of depression at the north, as he finds marine shells in the *boulder clay* of the St. Lawrence Valley; and he attributes much of the glaciation of Eastern North America to icebergs dragged over the submerged land.

Croll says ("Climate and Time," p. 391):

"The greater elevation of the land (in the Ice period) is simply assumed as an hypothesis to account for the cold. The facts of geology, however, are fast establishing the opposite conclusion, viz., that when the country was covered with ice, the land stood in relation to the sea at a lower level than at present, and that the continental periods or times, when the land stood in relation to the sea at a higher level than now, were the warm inter-glacial periods, when the country was free of snow and ice, and a mild and equable condition of climate prevailed. This is the conclusion toward which we are being led by the more recent revelations of surface-geology, and also by certain facts connected with the geographical distribution of plants and animals during the Glacial epoch."

According to the investigations of Bohtlingk and Kjerulf, Scandinavia was 600 feet lower during the Glacial period than now. Erdmann, on the contrary, supposes that Sweden was higher during the Glacial epoch than at the present day, from the fact that polished

[1] Some of the huge tabular icebergs, which have been observed off the Antarctic Continent, projected more than 500 feet above the surface of the ocean; and as for every foot above water there must have been 8.7 feet submerged, the whole thickness of the ice-sheet, from which these bergs were detached, must have been over 5,000 feet, and such a glacier must grind the sea-bottom to a depth of over 4,000 feet. (*See* Croll, "Climate and Time," p. 385.)

rock-surfaces extend beneath the sea; but this, as we have seen, proves no such thing.

Dana bases his statement that the northern portion of our continent was highest in the Ice period on the system of deep, now-buried channels, by which its surface was once furrowed, and upon the fiords which fringe the northern coast; but, as elsewhere stated, we have no proof that all, or nearly all, this erosion was not effected previous to the Glacial epoch. Reviewing all the facts that have been cited, we can at least say that the indications of elevation are not nearly so well marked in the Quaternary as in the Tertiary; and the evidence of such elevation as would shut out the tropical currents from the Arctic Sea in the Quaternary age is wholly wanting.

In the Champlain epoch the northern land was greatly depressed, as we learn from the fact that the clays containing marine shells are found on the present land at a constantly-increasing elevation as we go toward the north. About New York the Champlain clays reach from 50 to 100 feet above the ocean-level; on Lake Champlain they are 400 feet, at Montreal nearly 500 feet, at Labrador 800, in Barrow's Straits 1,000, and at the extreme point reached by the Polaris Expedition, on the coast of Greenland, 1,800 feet above the sea (Bessel).

On the European coast of the Atlantic we have proof of an elevation of the land during the Tertiary, and a subsidence in the Quaternary, similar to those described above. Hence we may infer that in the Champlain epoch the topography of the arctic regions was just that which would be favorable for the transfer by ocean-currents of the heat of the tropics to the arctic, and a prevalence over the arctic regions of a warm climate. But it must be said that all the shells found in the Champlain clays, from Lake Champlain to Greenland, are of a decided boreal character, which indicates that during the entire deposition of that formation a climate scarcely warmer than that of Greenland prevailed from New England northward.

If it is true that the Glacial epoch was one of elevation at the north—an elevation of the land much greater than the present—the change to the depressed condition of the Champlain epoch, when the sea stood from 1,500 to 1,800 feet higher on the coast of Greenland than it now does, must have been comparatively sudden; and if, as has been asserted, the depression of the Champlain epoch was common to the whole northern hemisphere, it could have been effected only by a great change in the figure of the earth, or by a flow of the ocean-waters into the polar regions, such as has been suggested by Adhemar and Croll. These writers hold the view that the effect of the extreme cold of the Glacial period was to form an ice-cap some miles in thickness over the arctic regions, and that this ice-cap moved the centre of gravity of the earth toward the pole, so that the oceanic waters flowed into this hemisphere and thus elevated the sea-level.

One result of the formation of an ice-cap over the polar regions alternately in one and the other hemisphere might very well be, as claimed by Croll and admitted by Sir William Thomson, such great ebbs and flows of the ocean-waters as we find recorded in the Champlain clays, and the present depressed sea-level; but some more conclusive evidence of an ice-cap will be asked by cautious reasoners than these alternations of level: such evidence, for example, as universal glaciation over all of North America of 40° north latitude. No such evidence has as yet been adduced; but, on the contrary, observers report an absence of ice-marks in the interior of the continent northwest of the Great Lakes. This we might take to be proof that the glaciers of the Ice period were limited to the highlands comparatively near the ocean, the source of evaporation, and that the interior was so dry then and now that no glaciers could be formed there. This is, however, a subject which requires further investigation. Whatever be its cause, the uniformity and magnitude of the change of sea-level from the Tertiary emergence to the Champlain submergence, and then to the present, render it one of the most remarkable phenomena recorded in geological history, and one that with careful study will probably throw much light upon the great dynamical influences that have produced changes on the earth's surface.

III. Either simultaneously or alternately with the extremes of warmth and cold, which we find recorded in the northern, warm and cold periods prevailed in the southern hemisphere. The evidences of a Glacial period in South America are as conclusive as on our own continent; but it is difficult to conceive how barriers could, at that time, have been thrown across the great open oceans—the South Atlantic and South Pacific—in such a way as to confine the tropical currents to the central portions of these oceans.

We are, perhaps, not justified in saying that such barriers never did exist, but it will be conceded that the difficulties which oppose their erection there are much greater than in the northern hemisphere; and the hypothesis which supposes their existence in the Glacial period of the southern hemisphere is so entirely unsupported by facts, that we are compelled to regard it as mere conjecture.

In any discussion of the phenomena and causes of the Ice period we are, up to the present time, somewhat limited and embarrassed for want of a wider range of observation. The facts are not yet all in. Nearly all the detailed and careful observations made on the glacial phenomena of the northern hemisphere have been limited to the eastern half of North America and the western part of the European Continent. Here the traces left by the glaciers are really stupendous in their magnitude and extent; and we have demonstrative evidence that, during the Ice period, the glaciers and snow-fields of Greenland stretched continuously down along the Atlantic coast of North America to and below New York, and that the highlands of New England

and Eastern Canada were completely covered, and probably deeply buried, in sheets of ice and snow. In the British Islands and Norway the inscriptions made by ancient glaciers are scarcely less broad and profound, and it is even conjectured that the bed of the shallow North Sea is itself glaciated throughout. These evidences of vast accumulations of ice and snow on the borders of the Atlantic have led some theorists to suppose that the Ice period was attended, if not in part caused, by a far more abundant evaporation from the surface of the Atlantic than takes place at present; and it has even been conjectured that submarine volcanoes in the tropics might have loaded the atmosphere with an unusual amount of moisture. This speculation seems to me, however, both improbable and superfluous; improbable, because no traces of any such cataclysm have been discovered, and it is more than doubtful whether the generation of steam in the tropics, however large the quantity, would produce glaciation of the polar regions. The ascent of steam and heated air loaded with vapor to the altitude of refrigeration, would, as it seems to me, result in the rapid radiation of the heat into space, and the local precipitation of unusual quantities of rain; and the effect of such a catastrophe would be slowly propagated and feebly felt in the arctic and antarctic regions. The hypothesis is superfluous, because all we want, to restore the conditions recorded in the glaciated area, is simply a depression of temperature; by this the climate of Greenland, with all the attending phenomena, would be brought down on both sides of the Atlantic to the lowest point where the average annual temperature of Greenland prevailed.

This is, I think, proved by the condition of Greenland itself; remote as it is from evaporating surfaces of warm water, the precipitation of moisture upon that continent is, however, sufficient to cover it deeply under sheets of snow and ice; the whole interior being occupied by a continental glacier; and it is easy to see that, with a depression of the average annual temperature 10°, the highlands of Labrador would be brought into the same condition. With a still further depression the elevated portions of New England, the Adirondacks, and the highlands north of the lakes, would be completely encased in snow and ice. If the flow of the St. Lawrence were arrested, and the annual precipitation of the region drained by it were congealed, and retained from year to year, glaciers would soon form, and creep down from the highlands into the valleys, until the basins of the great lakes and the troughs of the Hudson and St. Lawrence would be completely filled with ice. On the eastern side of the Atlantic this state of things would be still more rapidly reached, inasmuch as, from the effect of the Gulf Stream, the coast climate is considerably more moist.

So far, then, as the region bordering the North Atlantic is concerned, a simple depression of temperature from any cause whatever,

terrestrial or cosmical, would produce all the phenomena of the Ice period.

Before we can certainly determine, however, what the nature of the cause producing the cold of the Ice period was, we must know more accurately where and how the cause operated. To accomplish this, observations must be made over all those portions of the northern and southern hemispheres where the traces of former glaciers are visible.

In a general way we know that there was a cold period throughout the northern hemisphere, as glacial phenomena are reported from Siberia and Northwestern America, somewhat similar to those which we find on the Atlantic coast. In regard to Siberia very much remains to be learned. Nearly the whole of the northern portion of this great area is flat, and is deeply covered with Quaternary deposits; and it has been conjectured that in the Ice period the shallow sea off the Siberian coast was solidly frozen throughout a great portion of its breadth, and thus formed an ice-dam, behind which the drainage of the northern slope accumulated alternately as sheets of ice and bodies of fresh water.

The northern portion of the interior of our own continent is said to be without distinct marks of glacial action. Should this statement be confirmed by further observation, it would not, however, be a formidable argument against a general Glacial period; for intense cold would leave no permanent record there, unless there was sufficient precipitation of moisture to form glaciers. As this region is now very dry and sterile, it was perhaps so through the Ice period, and snow at no time fell there in sufficient quantity to form glaciers. On the mountains of British America and Alaska, of Oregon and California, there are abundant evidences of glaciers far more numerous and extensive than any now existing; and these furnish demonstrative evidence that this region shared in the effects of a distinct Ice period. The slopes of the Cascade Mountains in Oregon are everywhere glaciated, and perhaps no more impressive record of the Ice period exists than that formed by the planed and furrowed surfaces, the *roches moutonnées*, etc., by which all the higher portions of the belt, twenty to thirty miles in width, are marked. No ice-sheet moved in that region from the north, as there was no district of northern highlands where continental glaciers could be generated; but the glaciers radiated east and west from various centres along the crests of the chain, and descended at least 2,500 feet below the present snow line. This I determined by actual barometric observation in many places, and I nowhere found the lower limit of glacial action, as the planed and furrowed surfaces passed beneath the alluvium of the lower valleys.

Whether there was a depression of the Western coast during the Champlain epoch, corresponding to that recorded along the shores of the Atlantic, we are as yet unable to say, as careful observations on

this interesting subject are wanting; and these are not easily made on this iron-bound and earthquake-shaken coast, where there has been so little low and level land upon which Champlain clays could be deposited.

That this portion of the continent—like the Eastern side—has been higher than now, we learn from the deeply-excavated channels of the Golden Gate, the straits of Carquines, the mouth of the Columbia, the Canal De Haro, etc. But this erosion was produced in part if not altogether in Tertiary times. At Shoalwater Bay and about Steilacoom, there are raised beaches, apparently of ancient date, but farther south the changes of level have been so frequent and local that nothing like system has been educed from a comparison of the old shore-lines.

Taken as a whole, the glacial inscriptions of the West coast, as studied by King and Le Conte in California, and myself in Oregon, prove an Ice period as distinctly as do the glacial marks of the Atlantic coast and the Mississippi Valley; but the peculiar topography of the Western country has made the record a somewhat different one.

From the foregoing facts it seems to me that we are justified in concluding:

1. That however simple and plausible the Lyellian hypothesis may be, or however ingenious the extension or application of it suggested by Dana, it is not sustained by any proof, and the testimony of the rocks seems to be decidedly against it.

2. Though much may yet be learned from a more extended and careful study of the glacial phenomena of all parts of both hemispheres, the facts already gathered seem to be incompatible with any theory yet advanced which makes the Ice period simply a series of telluric phenomena, and so far strengthens the arguments of those who look to extraneous and cosmical causes for the origin of these phenomena.

A FITTING RECOGNITION OF AMERICAN SCIENCE.

PRESENTATION OF THE RUMFORD MEDAL BY THE AMERICAN ACADEMY OF SCIENCE TO DR. DRAPER.—FROM THE PROCEEDINGS OF THE ACADEMY.

AT the six hundred and eighty-ninth meeting of this body, held March 8, 1876, the chairman of the Rumford Committee introduced the *special* business of the evening, and handed to the President, Hon. Charles Francis Adams, the Rumford medals (in gold and silver), on each of which had been engraved the following inscription: "Awarded by the American Academy of Arts and Sciences to John W. Draper, for his researches in radiant energy, May 25, 1875."

In presenting the medals the President said:

GENTLEMEN OF THE ACADEMY: The foundation of this Society, you all know, dates back but four years less than a century. It followed close upon the adoption of the form of government of the State itself. Further than this privilege of a corporation, I am not aware that the State has since bestowed any aid on it whatever. During the long period that has intervened, the individual members have steadily and honestly contributed their labors and their money to the advancement of science and of the arts, the evidence of which is to be found as well in the collections of the library as in the long series of their published transactions. We have not been so lucky as to earn the favor of the generous and wealthy at all in the proportion given to some other institutions of the same general character. In point of fact, we have to ascribe our success more to our own energies than to the assistance of patrons. This is no bad sign for the future. The Academy was never in more healthy and vigorous condition than at this moment. The meetings are constantly attended by members who appear to give or to receive with interest the many valuable contributions to knowledge which ultimately take their place in the formidable volumes open to the inspection of the world.

Yet it is not to be understood from what I have said that the institution has been altogether without liberal assistance from several sources. The most remarkable instance of a benefaction was perhaps the earliest, that of Benjamin Thompson, better known under the name of Count Rumford, who, eighty years ago, presented to the Academy the sum of five thousand dollars, to be devoted to the stimulation of the study of the various phenomena connected with light and heat, by the presentation of medals of value as honorary rewards to successful research. It is to the credit of the Academy, in these degenerate days, to find that its administration of this property has fully justified the confidence of the donor, the original sum having increased more than fourfold over and above the cost of the medals which have from time to time been awarded to successful investigation of the great subjects proposed for study and examination.

It now becomes my agreeable duty to announce the fact that, after a careful review of the meritorious service of Prof. Draper in this great field of inquiry, the committee having the subject in their charge have, for reasons given by them, recommended through their chairman, that the medals prescribed in the deed of trust should be presented to him as having fully deserved them. It falls to my lot only to recapitulate in brief some of these reasons.

In 1840 Dr. Draper independently discovered the peculiar phenomena commonly known as Moser's images, which are formed when a medal or coin is placed upon a polished surface of glass or metal. These images remain, as it were, latent, until a vapor is allowed to condense upon the surface, when the image is developed and becomes visible.

At a later period he devised the method of measuring the intensity of the chemical action of light, afterward perfected and employed by Bunsen and Roscoe in their elaborate investigations. This method consists in exposing to the source of light a mixture of equal volumes of chlorine and hydrogen gases. Combination takes place more or less rapidly, and the intensity of the chemical action of the light is measured by the diminution in volume. No other known method compares with this in accuracy, and most valuable results have been obtained by its use.

In an elaborate investigation, published in 1847, Dr. Draper established experimentally the following important facts:

1. All solid substances, and probably liquids, become incandescent at the same temperature.

2. The thermometric point at which substances become red-hot is about 977° Fahr.

3. The spectrum of an incandescent solid is continuous; it contains neither bright nor dark fixed lines.

4. From common temperatures nearly up to 977° Fahr., the rays emitted by a solid are invisible. At that temperature they are red, and, the heat of the incandescing body being made continuously to increase, other rays are added, increasing in refrangibility as the temperature rises.

5. While the addition of rays so much the more refrangible as the temperature is higher is taking place, there is an increase in the intensity of those already existing. Thirteen years afterward Kirchhoff published his celebrated memoir on the relations between the coefficients of emission and absorption of bodies for light and heat, in which he established mathematically the same facts, and announced them as new.

6. Dr. Draper claims, and we believe with justice, to have been the first to apply the daguerreotype process to taking portraits.

7. Dr. Draper applied ruled glasses and specula to produce spectra for the study of the chemical action of light. The employment of ruled metallic specula for this purpose enabled him to avoid the absorbent action of glass and other transparent media, as well as to establish the points of maximum and minimum intensity with reference to portions of the spectrum defined by their wave-lengths. He obtained also the advantage of employing a normal spectrum in place of one which is abnormally condensed at one end and expanded at the other.

8. We owe to him valuable and original researches on the nature of the rays absorbed in the growth of plants in sunlight. These researches prove that the maximum action is produced by the yellow rays, and they have been fully confirmed by more recent investigations.

9. We owe to him, further, an elaborate discussion of the chemical

action of light, supported in a great measure by his own experiments, and proving conclusively, and, as we believe, for the first time, that rays of all wave-lengths are capable of producing chemical changes, and that too little account has hitherto been taken of the nature of the substance in which the decomposition is produced.

10. Finally, Dr. Draper has recently published researches on the distribution of heat in the spectrum, which are of the highest interest, and which have largely contributed to the advancement of our knowledge of the subject of radiant energy.

And now, in the absence of Dr. Draper, unable at this inclement season to execute a fatiguing journey, it gives me pleasure to recognize you, Mr. Quincy, as his worthy and competent representative.

I pray you, in receiving these two medals on his behalf, in accordance with the terms of the original trust, to assure him, on the part of the Academy, of the high satisfaction taken by all its Fellows in doing honor to those who, like him, take a prominent rank in the advance of science throughout the world.

Mr. Quincy, on receiving the medals, said:

MR. PRESIDENT: In the name and on the behalf of Dr. Draper I have the honor to receive the Rumford medals in gold and silver, which the Academy has been pleased to award to him, and I will have them safely conveyed to him to-morrow, together with the assurances of the satisfaction of the Academy in this action which you wish me to communicate to him. In common with yourself, sir, and all the Fellows present, I regret that that eminent person is unable to attend this meeting and receive the medals himself. And, personally, I regret the absence of Dr. Wolcott Gibbs, who had promised to perform this grateful service for his friend, and who would have been able to make a more suitable reply to the able discourse with which you have accompanied the presentation of the medals, and to have done more justice to the claims of Dr. Draper to this distinction than I can pretend to do. Dr. Gibbs having also been unavoidably prevented from being present this evening, I have now the honor to read a communication from Dr. Draper to the Academy, in acknowledgment of this testimony to his services to science.

Mr. Quincy then read the following letter:

TO THE AMERICAN ACADEMY OF ARTS AND SCIENCES: Your favorable appreciation of my researches on radiations, expressed to-day by the award of the Rumford medals, the highest testimonial of approbation that American science has to bestow on those who have devoted themselves to the enlargement of knowledge, is to me a most acceptable return for the attention I have given to that subject through a period of more than forty years, and I deeply regret that through ill-health I am unable to receive it in person.

Sir David Brewster, to whom science is under so many obligations for the discoveries he made, once said to me that the solar-spectrum is a world in itself, and that the study of it will never be completed. His remark is perfectly just.

But the spectrum is only a single manifestation of that infinite ether which

makes known to us the presence of the universe, and in which whatever exists —if I may be permitted to say so—lives and moves and has its being.

What object, then, can be offered to us more worthy of contemplation than the attributes of this intermedium between ourselves and the outer world?

Its existence, the modes of motion through it, its transverse vibrations, their creation of the ideas of light and colors in the mind, the interferences of its waves, polarization, the conception of radiations and their physical and chemical effects—these have occupied the thoughts of men of the highest order. The observational powers of science have been greatly extended through the consequent invention of those grand instruments, the telescope, the microscope, the spectrometer. Through these we have obtained more majestic views of the nature of the universe. Through these we are able to contemplate the structure and genesis of other systems of worlds, and are gathering information as to the chemical constitution and history of the stars.

In this noble advancement of science you, through some of your members, have taken no inconspicuous part. It adds impressively to the honor you have this day conferred on me, that your action is the deliberate determination of competent, severe, impartial judges. I cannot adequately express my feelings of gratitude in such a presence, publicly pronouncing its approval on what I have done.

I am, gentlemen, very truly yours, JOHN W. DRAPER.

BLASIUS'S THEORY OF STORMS.[1]

BY PROF. VICTOR L. CONRAD, M. A.

I PROPOSE to give some account of a new theory of storms put forth by Prof. Blasius, of Philadelphia, formerly Professor of Natural Sciences in the Lyceum of Hanover, Germany. His attention was first drawn to the subject of storms in the year 1851. Having witnessed the destructive effects of a tornado at West Cambridge, Massachusetts, he made a careful survey of its entire track. The facts discovered about the middle of its course, where the most damage had been caused, favored the rotary theory of Redfield; those near the end of its path seemed to confirm the inblowing theory of Espy; but those at the beginning could not be explained by either theory. Discouraged and perplexed by these conflicting results, he resolved to apply to storms the analogy drawn from the life of an animal in its origin or embryo, its development to maturity, and its end. From this he argued that storms must have a beginning, a duration, and an end, with phases peculiar to each stage of their development and progress, like an animal; and, guided by this analogy, he made a careful reëxamination and application of all the facts he had

[1] "Storms: Their Nature, Classification, and Laws, with the Means of predicting them by their Embodiments the Clouds." By William Blasius. Philadelphia: Porter & Coates.

discovered, and came to the following conclusion respecting the origin and distinct character of tornadoes and storms:

ORIGIN OF STORMS AND TORNADOES.—"I had found the existence of two opposing currents of air of different temperature, coming respectively from northwest and southwest, acting suddenly against each other after a sultry calm of some duration; and shortly, a third gyratory force making its appearance between them, traveling in their diagonal, growing to such magnitude as to obliterate all trace of the straight-line forces of the opposing currents, and finally abruptly disappearing. The two currents must have been, during the period of sultry calm, in a state of equilibrium, since the clouds were observed to remain for some time almost stationary. South of the tornado's track the southwest wind prevailed until the beginning of the tornado, and, from information obtained for me by ex-President Hill, it appeared that a storm had traveled from northwest to southeast over the States of New Hampshire and Vermont, and that during its progress a southwest wind was replaced by a northwest wind. I was thus led to conclude that the storm announced that afternoon by the black bank of cloud consisted in the conflict of two aërial currents of different temperature—that the colder northern current displaced the warmer southern current in the direction from northwest to southeast, gradually decreasing in velocity until, north of Waltham, West Cambridge, and Medford, it came to a perfect standstill, producing the sultry calm felt before the tornado.

"Here the two currents, being in equilibrio, exerted a great compressive force against each other. The equilibrium was disturbed by the uneven configuration of the earth around Prospect Hill. This disturbance produced the tornado, which traveled, not in the direction of the storm toward the southeast, but in the diagonal of the two opposing currents over their region of calm at their line or meeting, and in and underneath the black bank of clouds stretched out from west to east which must have marked this line of meeting.

"I came thus to two distinct phenomena—the tornado, and the storm in the ordinary sense of the word—both different in their origin, nature, direction, progress, and appearance, and governed by entirely different laws."

Continuing his observations for several years, he came to the conclusion—

"That storms in the temperate zone at least, and over the United States, are the *effect* of the conflict of opposing aërial currents of different temperatures, and not the *cause* of these currents and temperatures, as seems to be assumed by some cyclonists."

Continuing and extending his observations and studies in the general field of meteorology, our author compares his own method of procedure with that usually pursued by others, as follows:

"Having found, during my investigations, that tornadoes and other storms are different phenomena, and that they follow different laws, I endeavored to investigate storms in general by the same method I had used with the tornado.

"My researches were not made by filling out the ordinary meteorological formulæ from observations made three or four times daily, as is the custom. I had learned that no storm will be accommodating enough to develop itself just at the specified periods for observing; I do not believe that this method will ever lead to any definite results.

"A storm must be treated as an individual which is subject to development. This is difficult, on account of the nature of the subject, but it is possible and essential. We must take the storm at its earliest appearance, and not lose sight of it for one moment until we know it throughout its whole extent, in all its parts, from beginning to end."

This view of Prof. Blasius coincides with that of Sir William Herschel, who says:

"In endeavoring to interpret the weather, we are in the position of a man who hears at intervals a few fragments of a long history related in a prosy, unmethodical manner. A host of circumstances omitted or forgotten, and the want of connection between the parts, prevent the hearer from obtaining possession of the entire story."

DEFINITION OF A STORM.—But leaving methods and passing to results, our author defines a storm in general to be "*the movement of the air caused by its tendency to reëstablish an equilibrium which has been disturbed;* and we may call all such movements storms, whether they are gentle breezes or furious hurricanes, whether accompanied by more or less condensation of moisture or clouds, or even by none at all," as in deserts.

CLASSIFICATION OF STORMS.—As the result of his investigations in aërial movements in the northern hemisphere, Prof. Blasius presents the following classification of all storms:

1. LOCAL OR VERTICAL STORMS. Stationary. Centripetal.—Produced by a tendency of the atmosphere to reëstablish in a vertical direction an equilibrium that has been disturbed. Characteristic cloud—*cumulus.*

2. PROGRESSIVE OR LATERAL STORMS. Traveling.—Produced by a tendency of the atmosphere to reëstablish in a lateral direction an equilibrium that has been disturbed. They are of two kinds:

(*a.*) EQUATORIAL OR NORTHEAST STORMS. Winter storms.—Produced by a warm current displacing a cool one to supply a deficiency toward the poles. Temperature changing from cool to warm.—Direction to the northeastern quadrant. Characteristic cloud—*stratus.*

(*b.*) POLAR OR SOUTHEAST AND SOUTHWEST STORMS. Summer storms.—Produced by a cool current displacing a warm one to supply a deficiency toward the equator. Temperature changing from warm to cool. Direction to the southern semicircle. Characteristic cloud—*cumulo-stratus.*

3. LOCO-PROGRESSIVE OR DIAGONAL STORMS. Traveling locally. Rotary—tornadoes, hailstorms, sandstorms, water-spouts, etc.—Produced by a tendency of the atmosphere to reëstablish the equilibrium of a *polar storm* which has been disturbed in the plane of meeting by a peculiar configuration of the ground.—Direction, the diagonal of the forces of the two opposing currents transversely through the polar storm.—Characteristic cloud—*conus.*

In order that the significance of the above classification may be clearly understood, it will be well to notice in brief outline the general movements of the atmosphere surrounding the globe, more especially those in the northern hemisphere.

ATMOSPHERIC CURRENTS.—All storms owe their origin to the heat of the sun, which produces differences of temperature in different portions of the earth, and thereby causes all the movements and currents which take place in the atmosphere around the globe. As the air at the equator is more highly heated by the sun than that of any other region, it expands, becomes lighter and rises, causing a partial vacuum or deficiency there at the surface of the earth. The air north and south of it at once moves forward from opposite directions to supply this deficiency at the equator, and this in turn becomes heated and ascends. Other air again moves forward from north and south to replace it, and thus an upward current at the equator, and a north and south polar current at the surface toward the equator, are established. These north and south polar currents cause a deficiency of air at the poles, and the heated air which has risen at the equator into the upper region of the atmosphere divides and moves forward toward the opposite poles to supply the deficiency caused there. Thus, upper currents in opposite directions from the equator to the poles are also established in order to restore the equilibrium disturbed by the surface polar currents flowing toward the equator.

But by the time the air of the upper currents has reached the region of the tropics, it has become cooler and heavier, and descends to the surface of the earth. Here it divides into two currents—one flowing back to the equator, forming the trade-winds; and the other, becoming warmer again at the surface, flows toward the poles, meeting the polar current somewhere north of the tropic in the northern hemisphere, and south of it in the southern. *This meeting of the equatorial or tropical and polar currents in the temperate zone, and the various phenomena attending and resulting from it, are the most significant and important facts which constitute the basis of Prof. Blasius's theory of storms*, in distinction from the centripetal theory of Espy, and the rotary theory of Colonel Clapper, as developed by Piddington, Thom, Dove, and others, and better known in this country as the cyclone theory of Redfield.

The following diagram (Fig. 1) will serve to indicate the movements and courses of the general atmospheric currents of the earth, as above described, the arrows showing the directions in which they move.

The two currents above referred to—the polar and the equatorial or tropical—are of different temperatures, and move horizontally in opposite directions toward each other. When they meet they overlap each other somewhat like two wedges with their sharp ends forward. The warmer current, being lighter, glides obliquely over the cooler current, and moves northward; and the cooler current, being heavier, moves beneath it on the surface of the earth southward, just as two currents, warm and cold, flow over each other in opposite directions through an open window or door of a heated room.

The plane of meeting between these two currents is more or less inclined northward in the northern hemisphere, for the reason just stated; and the lower end of the plane, or the space of air between these two currents where they meet on the surface of the earth,[1] constitutes the centre line or area proper of the storm, and the region of lowest barometer. The horizontal plane beneath this inclined plane[2]

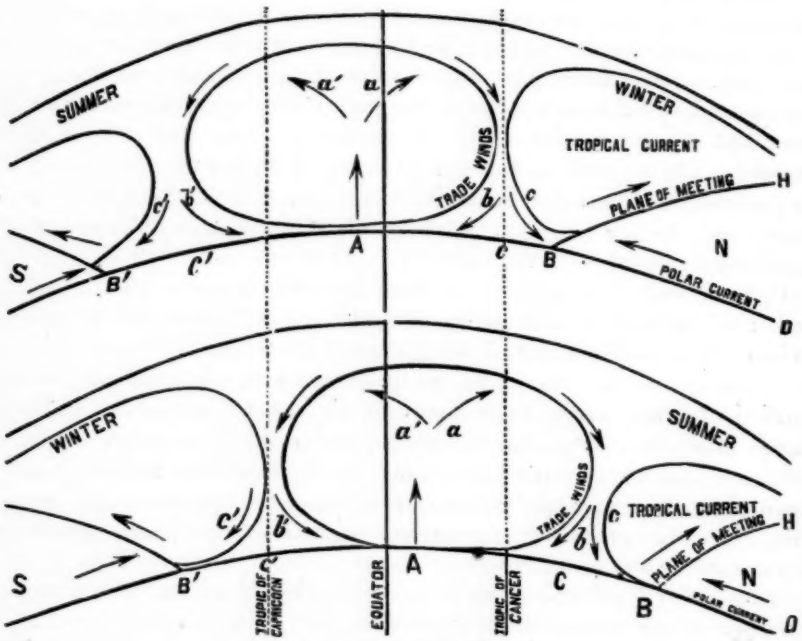

FIG. 1.—ATMOSPHERIC CURRENTS.

is the geographical extent of the region affected by the storm and the region of low barometer. The place where the currents meet is constantly changing with the changing seasons, following the sun northward in summer and southward in winter. These changes of locality do not, however, take place in one continuous movement of the atmosphere; but with successive oscillations, like the waves of a rising tide, each succeeding wave advancing farther and receding less than the one before it, until its most northern or southern limit is reached —as represented by the numbers 1 and 2 in the diagram— when the oscillations in the opposite direction again begin. Whenever the lower end of the plane of meeting between the two opposing currents at *B* oscillates or passes over any place on the surface of the earth, it will cause storm or change of weather there—a change of wind, of temperature, and of atmospheric pressure.

The inclination of the plane of meeting, or the slope of the tropi-

[1] As shown at *B* in the diagram.

[2] From *B* to *D*.

cal current over the polar, varies with the seasons and local circumstances. In winter the slope between the two currents is very gradual, as there is less difference of temperature, and less power of resistance between them. The warm current passes over the cold at a gentle inclination (as represented by the line *B H* in Fig. 1); and thus the horizontal or geographical extent of the storm beneath it—from *B* to *D*—which is the region of low barometer, is much enlarged, and sometimes its oscillations extend or move over several hundred miles.

In summer, however, the difference of temperature between the two currents, and their power of resistance, are greater, and when they meet they bank up against each other with more momentum and force, and the plane of meeting or conflict is often very steep and sometimes almost vertical (as indicated by *B H* in Fig. 2). Hence, the geographical extent of a storm in summer is much less than in winter, and the region of low barometer which moves with it is correspondingly small.

Clouds the Precursors of Storms.—Whenever a warm current of air, saturated with moisture, meets or mingles with a cold current, the invisible moisture of the warm air is condensed into visible vapor or clouds. As storms are produced by the movements and conflicts of warm and cold currents of air, the formation of clouds always indicates to the observer the region in the atmosphere where such movements are taking place, which would otherwise be invisible. Clouds, therefore, are the invariable precursors of storms, and the kind of clouds formed will indicate the kind of storm or atmospheric movements which produce them.

This general fact, however, does not apply to deserts, where the moisture of the warm air is condensed and precipitated before it meets the cooler air, and hence rain-clouds are seldom or never formed by the sand-storms of deserts.

Classification of Clouds.—Whenever, on account of some topographic circumstances, the sun heats any locality on the surface of the earth more than the surrounding region, a gentle current or column of heated air rises, and its invisible moisture is condensed into small masses of clouds called *cumuli*, which spread and produce the mottled appearance commonly known as "mackerel sky," as indicated at 1 in the accompanying illustration (Fig. 2).

But when, as is frequently the case in summer, a valley or plain, or island, or any other place, is much more highly heated by the sun than the surrounding region, the heated air over such locality rises more rapidly and with more ascensional momentum; and, as it reaches the higher and cooler regions of the atmosphere, its moisture is condensed into large rounded volumes, or mountain-like masses of *cumulus* clouds, as indicated at 2 in the illustration. Such *cumulus* clouds always precede and characterize a local summer storm or shower.

When the warm horizontal current from the south, as in winter,

meets with the cold current from the north, it slopes upward over the cooler current, and forms stripes or bands of *stratus* clouds along the horizon, as shown in Fig. 3.

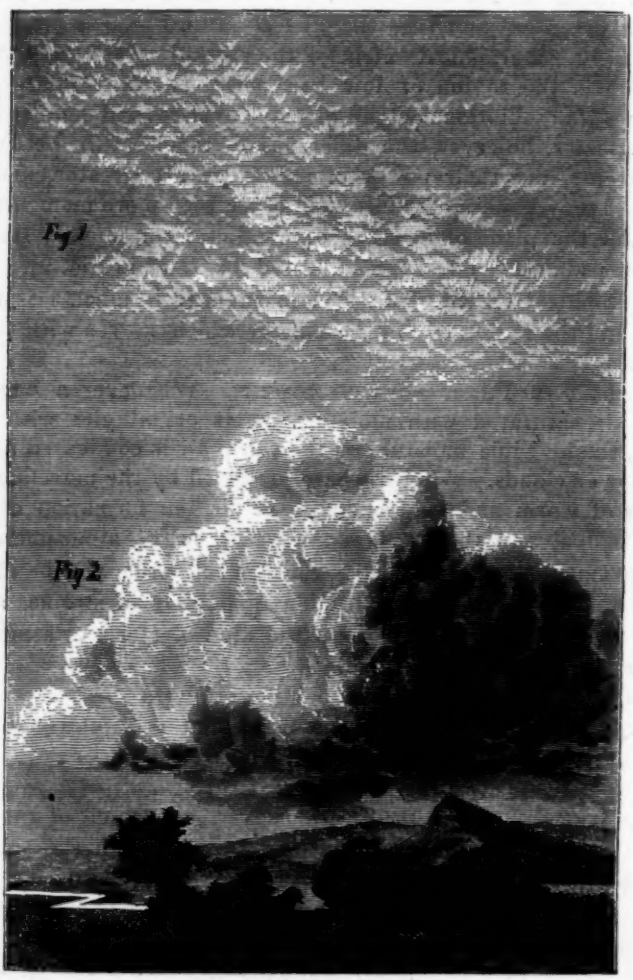

FIG. 2.—CUMULUS CLOUDS.

These *stratus* clouds indicate to the observer the fact that a warm current is coming northward.

When in summer a cool current is moving southward, it encounters the warm equatorial or tropical current, which again glides upward and over it, and forms horizontal bands of *stratus* clouds along the upper line of contact, as in winter storms; but, in addition, the denser cold air from the north, moving with more momentum, will lift up the warm and saturated air from the tropics, and its moisture

will be condensed into masses of *cumulus* clouds banked up against the top of the cold current, and arranged over the horizontal *stratus* clouds. Thus is produced the combination of *cumulo-stratus* cloud, as represented in Fig. 4, and which is characteristic of progressive summer storms.

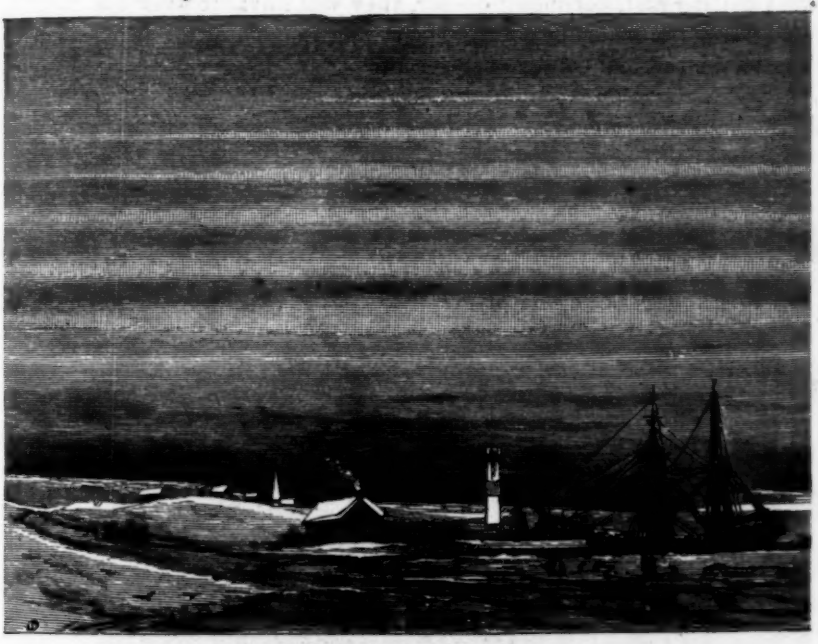

FIG. 3.—STRATUS CLOUDS.

To the tornado-cloud produced by a whirl of air, and resembling an inverted cone, Prof. Blasius gives the name of *conus*, which is both distinctive and appropriate.

These four typical classes of clouds—viz., cumulus, stratus, cumulo-stratus, and conus—indicate and characterize the four different classes of storms.

PREDICTION OF STORMS.—With the foregoing facts and classifications in view, Prof. Blasius's method of predicting the approach of storms, "by their embodiments the clouds," can be verified by any careful observer of ordinary intelligence.

WINTER STORMS.—When in winter, while the wind is blowing from the north, thin, hazy bands or stripes of *stratus* clouds appear low in the southern horizon, it indicates that the warm current from the south is flowing northward, sloping over the polar current, and that the condensation of its vapor into clouds, by successive undulations, has commenced in the upper and colder regions of contact. More and more of these *stratus* clouds gradually appear, until they cover the entire southern sky and reach the zenith. This may require

from twelve to twenty-four hours, or longer. Sometimes these clouds, before reaching the zenith, will recede and disappear beneath the southern horizon. This indicates a backward oscillation of the southern current, caused by the greater resistance of the polar current. But in such case the *stratus* clouds will reappear next day, or sooner, and uniting and, becoming denser, they will advance over the zenith, and cover the whole heavens, discharging rain, snow, or sleet, according to the thermal conditions present.

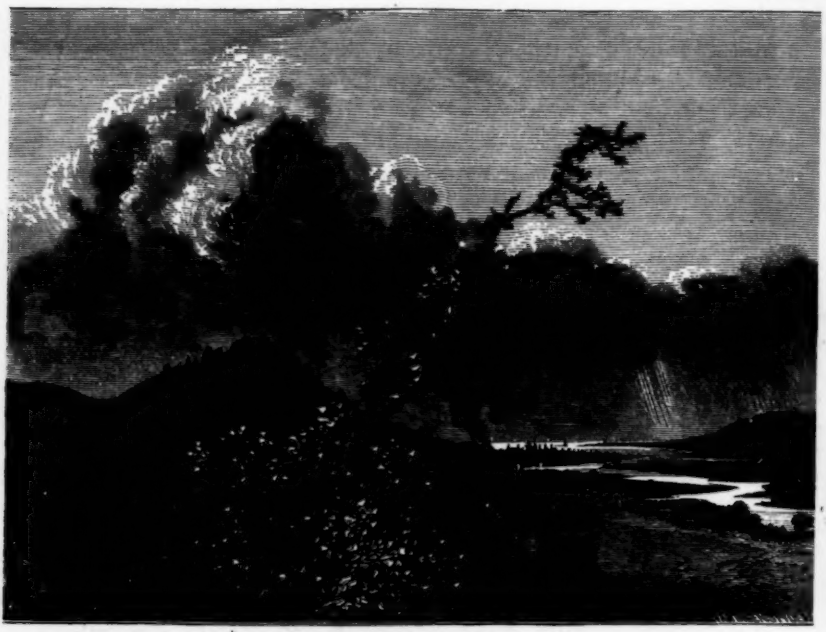

FIG. 4.—CUMULO-STRATUS CLOUDS.

Thus, by observing the clouds, a northeast or winter storm may always be predicted from one to three days beforehand, while the barometer shows no change until the *stratus* clouds from the south have reached and passed over the zenith, when it begins to fall; but the thermometer indicates no change.

At this stage of the storm the wind from the north rises and blows more violently, while the clouds move northward against the wind, and the rain or snow, driven by the prevailing wind, comes down obliquely from the north. After some time the direction of the wind changes, and there is a calm. The air is warmer, the thermometer rises suddenly, the barometer has reached its lowest point, and the rain or snow falls vertically. This calm continues for a longer or shorter time, and the wind gradually changes until it comes from nearly or quite the opposite quarter from which it came at the beginning of the storm, and blows more powerfully than before. The

barometer now rises again, but is not as high as before the storm, because it is in the tropical current which has reached the locality. If, now, the wind from the south, which has prevailed and driven back the northern current, continues in the same direction until the entire atmospheric area of the storm passes over the zenith northward, and the sky clears up from the south or southwest, as is generally the case in early autumn or late spring, then the next storm or change of weather will come from the north. But if the wind changes its direction again before the storm is over, as is mostly the case in mid-winter, and blows from the north, as it did at the beginning, until the entire atmospheric area of the storm is carried backward over the zenith, and the sky clears from the north, then the next storm or change of weather will come from the south, as described above. In this case the polar current has prevailed, the air is colder, the thermometer falls, the barometer rises higher than in the other case, and the atmospheric conditions existing before the storm are gradually reëstablished.

Summer Storms.—Before a progressive summer storm, the air is usually warm and sultry, the sky cloudless but somewhat dim, and a light southerly breeze is blowing. Suddenly the sound of distant rumbling thunder is heard, and large masses of dark *cumulus* clouds rise and arrange themselves on a long bank of *stratus* clouds in the northern or northwestern horizon. This is the *cumulo-stratus* combination of clouds which is the herald of a polar or progressive summer storm. Soon the south wind increases in violence, and drives clouds of dust before it. The thunder rolls, and lightning flashes more frequently. The clouds bank up higher and higher, and advance more slowly, until at last they become stationary. These are the ordinary indications of a violent progressive summer storm, which sometimes ends in a tornado.

Like a winter storm, it is produced by the meeting and conflict of the polar and tropical currents under greater differences of temperature and other conditions, and is therefore attended with more violent and complex phenomena than those of a winter storm. The changes of wind, and of the barometer and thermometer, during its development at any locality, are similar to those of a winter storm *in its return oscillation southward;* that is, these changes occur in a reverse order to those of a winter storm during the regular progress of the tropical current northward, in the same order as during its oscillation southward.

In most cases of this kind of summer storms, after the clouds have remained stationary for some time, discharged their rain and restored the disturbed equilibrium of the atmosphere, the polar current which produced it by moving southward oscillates back to the north again, and the storm at this locality is over—although similar phenomena and changes will be occasioned by it later at other localities over which it sweeps in its oscillation northward.

The *cumulo-stratus* cloud, which is the precursor of this kind of storm, can usually be observed only from one to eight hours, and, in some cases of the most violent kind, only about twelve hours before it will burst upon a place. Although these storms are the most dangerous and destructive—not unfrequently ending in tornadoes and hurricanes—the barometer is of no practical service in predicting it. This is explained by the fact that in such storms the plane of meeting of the two currents moves southward with its lower extremity, or region of lowest barometer, *in front*, while the plane itself is more or less inclined northward. Hence the barometer shows no change until this region of lowest barometer moves over it, when it suddenly falls; but it is then already in the most dangerous part of the storm, and its warning, therefore, comes too late; while the clouds, if properly observed, always give warning in time to provide against the dangers of such a storm.

Tornadoes.—This class of storms includes hailstorms, waterspouts, hurricanes, and all storms in which rotary and lateral motions are more or less combined. They are the most violent and destructive of all storms, as well as the most complicated and difficult to understand and explain. They are the offspring of progressive polar or summer storms, and in the temperate zone occur only during summer.

When in the development of a summer storm, as above described, the two conflicting currents attain a state of equal power or resistance, and thus balance each other, which is indicated when the dense *cumulus* clouds over the plane of conflict become stationary, then the storm is at its crisis. The air within the region of conflict is compressed and very sultry, and this condition is always felt before a tornado by persons within its area. If, now, during this critical stage of the storm, no topographic or other disturbance of its tension take place in its plane of meeting, a return oscillation of the polar current northward will set in, and the storm will gradually clear away. But if, in this crisis of the storm and during this high state of compression and resistance, either current becomes stronger, and forces back the other over some hill or valley, or if some other obstruction or configuration of the surface of the earth breaks the tension or disturbs the resistance between the two currents at any point, so that the polar current will sink as in a valley, then the tropical current will suddenly rush into this depression and generate a succession of violent whirling and zigzag motions along the diagonal of the two currents within the plane of conflict, as the waters of a dam would rush through a sudden break or depression in an embankment. This conclusion respecting the origin of tornadoes Prof. Blasius reached after his careful study of the West Cambridge tornado of 1851, and it was subsequently confirmed by the facts and phenomena connected with the tornado of Iowa and Illinois, in May, 1873, as obtained from the report of the

United States Signal Service for that year, as well as by those of other tornadoes.

The characteristic cloud of a tornado is the *conus*, which appears first above as a dense, dark disk, and is formed by the whirl of the tropical current rushing into the depression of the polar current which starts the tornado, and it is enlarged and lengthened by alternate and rapid condensations above and below, as the tropical air whirls and zigzags along the diagonal of conflict, until sometimes the *conus* above and below unite—as in the case of water-spouts at sea—and a rotating column of mingled air, dense cloud, dust, or water—as the case may be—is thus formed, and sweeps along the plane of meeting between the opposing currents, and beneath the bank of *cumulus* clouds which mark the area of a tornado's path of destruction.

The *conus* cloud, however, as above described, is only formed when the tornado has already commenced, and is therefore of no use to indicate its occurrence beforehand.

But when the dark and dense masses of *cumulus* clouds in a summer storm cease moving forward or laterally, but bank up higher and higher, and there is great commotion among them, and when there is an oppressive sultriness about the air, these phenomena always indicate that the suspended storm is in a crisis or condition to generate a tornado, in case some local obstruction or other cause disturb the equilibrium of resistance between the two conflicting currents.

Scientific Aspects.—The condensed result of modern meteorological science is the general fact announced by Prof. Buys-Ballot, of Utrecht, that "*the wind always blows from the place of highest to that of lowest barometer*, turning by the rotation of the earth to the right on the northern hemisphere, and to the left on the southern hemisphere." This is known as "Ballot's Law," and is the chief basis of all scientific weather predictions at the present day.

The first part of this law, given in italics, is found to be universally correct. The second part, however, has many exceptions, and is as often "honored in the breach as in the observance;" for, in polar storms, the winds from the northern semicircle do not conform to it.

Among other definite results attained by barometric observations and deduced from Ballot's law, is the fact that the rain-area of a storm extends over that of lowest barometer and also surrounds it. The isobars, or elliptic lines, of equal barometer, surround the area of lowest barometer, and the most distant isobar marks the limit of the region of low barometer, and may be regarded as the boundary between the regions of high and low barometer. The gradients indicate the differences of pressure between the isobars on a line extending at right angles from that of highest to that of lowest barometer.

The shape of the area of *lowest* barometer in a progressive storm is that of an irregularly elongated ellipse, moving sideways, or in the direction of its shortest diameter; and the gradients are found to be

much more steep on the southward than on the northward side of this area; from which it follows that the rain-area is much less on the southward than on the northward side of a progressive storm.

All the atmospheric changes and phenomena above stated result from the same general cause, but under different conditions and circumstances. This cause is the meeting of the polar and tropical currents in their movements northward and southward, to restore a disturbed equilibrium in the atmosphere toward the equator or the poles.

Applying this theory in brief explanation of the facts stated in connection with Ballot's law, we find the area of *lowest* barometer at the place where the two currents meet on the surface of the earth. It is produced by the obliquely upward movement of the tropical current over the polar current, and by its rising more or less vertically in the vicinity of contact, after its horizontal progress northward has been checked by encountering the polar current. This oblique and upward movement of the tropical current diminishes the atmospheric pressure there, as shown by the barometer, and produces that depressing calm which is always felt by persons in any locality where this meeting of currents takes place, or over which its area moves or oscillates during the continuance of a storm. The elongated, elliptical shape of this area is accounted for by the fact that it is the narrow space between the two currents where they meet, and extends eastward and westward between them. It is rounded at the ends or margins of the currents, where the wind, in accordance with Ballot's law, blows inward toward the centre line of contact, which is also the centre line of lowest barometer. And, as the two currents force each other backward and forward during a storm, they necessarily carry along the elliptical space between them, and thus its movements in the direction of its shorter axis are accounted for.

The rain-area, or that of low barometer, which surrounds the elliptical region of lowest barometer where the currents meet on the surface, as just explained, extends horizontally beneath the plane of meeting, which is inclined northward. It is produced chiefly by the oblique and upward movement of the tropical current over the polar.

The gradients, or different degrees of pressure within the rain-area, are caused by the same upward movement of the tropical current over the polar, in connection with the constantly-varying heights or depths of both polar and tropical air, which are vertically above the space beneath the inclined plane from the region of lowest to that of highest barometer northward; and the steeper or more abrupt gradients southward are explained by the fact that when the tropical current meets the polar current it is suddenly checked, and while a portion of it moves obliquely over the polar current, as stated, another portion of it rises, more or less vertically, for some distance around the vicinity of contact, and the pressure is thus more suddenly diminished on the southward side of this area of low barometer than on

the northward, where it slopes more gradually beneath the inclined plane of meeting, as above explained.

For obvious reasons, the region of high barometer is within the polar current before it meets the tropical, and also within the tropical current before it is disturbed, or its horizontal movement checked by meeting the polar current; but the barometer is highest in the polar current, because it is colder and denser.

In addition to the foregoing facts which barometric observations have established, this theory of opposing currents explains a great many other aërial problems and phenomena which have not heretofore been adequately accounted for. Among these are the real causes of different kinds of storms and how they originate; why they move forward and backward, carrying the lines and areas of high and low barometer, of isobars and gradients, with them, and why they cease; why the barometer indicates the approach of some storms in advance, but is useless in others; why it falls in some storms but rises in others; why a progressive storm travels *against* the prevailing wind, and why the wind changes during its progress; why there is a region of calm, and why the wind is stronger around this region of calm. It explains how snow-storms change to rain, or sleet and rain, and why it falls obliquely toward the direction from which the storm is coming; also why in some storms the rain falls in advance of the area of low barometer and in the rear of it in others. It accounts for the origin of tornadoes, water-spouts, hail-storms, and all other whirling storms, and explains why these always move in an eastward direction on our continent. It explains why the rain-areas of winter storms are more extended than those of summer, why their approach is slower and their continuance longer, and why they produce sudden changes of temperature in their progress over any place. It greatly simplifies and corrects previous explanations respecting the formation of different kinds of clouds, and accounts for the development of electricity both in summer and in winter storms.

ORDEALS AND OATHS.

By EDWARD B. TYLOR.

IN primitive stages of society, the clannish life of rude tribes may well have been more favorable to frank and truthful relations between man and man than our wider and looser social intercourse can be. Yet one can see, from the habits of modern savages, that already in early savage times society was setting itself to take measures against men who broke faith to save themselves from harm or to gain some coveted good. At the stage of civilization where social

order was becoming regular and settled, the wise men turned their minds to devise guarantees stronger than mere yes and no. Thus the ordeal and the oath were introduced, that wrong-doing should not be concealed or denied, that unrighteous claims should not be backed by false witness, and that covenants made should not be broken.

The principles on which these ordeals and oaths were invented and developed may to this day be plainly made out. It is evident that the matter was referred to the two intellectual orders of early times, the magicians and the priests. Each advised after the manner of his own profession. The magician said, "With my symbols and charms I will try the accused, and bind the witness and the promiser." The priest said, "I will call upon my spirits, and they shall find out the hidden thing, and punish the lie and the broken vow." Now, magic and religion are separate in their nature and origin. *Magic* is based on a delusive tendency arising out of the association of ideas, namely, the tendency to believe that things which are ideally connected in our minds must therefore be really connected in the outer world. *Religion* is based on the doctrine of spiritual beings, souls, demons, or deities, who take cognizance of men and interpose in their affairs. It is needful to keep this absolute distinction clear in our minds, for on it depends our finding our mental way through a set of complicated proceedings, in which magical and religious elements have become mixed in the most intricate manner. Well they might, considering how commonly the professions of sorcerer and priest have overlapped so as even to be combined in one and the same person. But it seems, from a general survey of the facts of ordeals and oaths, that on the whole the magical element in them is earliest and underlying, while the religious element is apt to come in later in history, often only taking up and consecrating some old magical process.

In the series of instances to be brought into view, this blending of the religious with the magical element will be repeatedly observable. It will be seen also that the ordeal and the oath are not only allied in their fundamental principles, but that they continually run into one another in their use. Oaths, we shall see, may be made to act as ordeals, and ordeals are brought in as tests of oaths. While recognizing this close connection, it will be convenient to divide the two and take them in order according to their practical application, ordeals being proceedings for the discovery of wrong-doers, while oaths are of the nature of declarations of undertakings.

The association of ideas which serves as a magical basis for an ordeal is quite childish in its simplicity. Suppose it has to be decided which of two men has acted wrongfully, and appeal is had to the ordeal. There being no evidence on the real issue, a fanciful issue is taken instead, which can be settled, and the association of ideas does not rest. Thus in Borneo, when two Dyaks have to decide which is in the right, they have two equal lumps of salt given them to drop

together into water, and the one whose lump is gone first is in the wrong. Or they put two live shell-fish on a plate, one for each disputant, and squeeze lime-juice over them, the verdict being given according to which man's champion-mollusk moves first. This reasoning is such as any child can enter into. Among the Sandwich-Islanders, again, when a thief had to be detected, the priest would consecrate a dish of water, and the suspected persons, one by one, held their hands over it, till the approach of the guilty was known by the water trembling. Here the connection of ideas is plain. But we may see it somewhat more fully thought out in Europe, where the old notion remains on record that the executioner's sword will tremble when a thief draws near, and even utter a dull clang at the approach of a murderer.

Starting with the magical ordeal, we have next to notice how the religious element is imported into it. Take the ordeal of the balance, well known to Hindoo law. A rude pair of scales is set up with its wooden scale-beam supported on posts; the accused is put in one scale, and stones and sand in the other to counterpoise him; then he is taken out, to be put in again after the balance has been called upon to show his guilt by letting him go down, or his innocence by raising him up. This is pure magic, the ideal weight of guilt being by mere absurd association of ideas transferred to material weight in a pair of scales. In this process no religious act is essential, but in practice it is introduced by prayers and sacrifices, and a sacred formula appealing to the great gods who know the walk of men, so that it is considered to be by their divine aid that the accused rises or falls at once in material fact and moral metaphor. If he either goes fairly up or down the case is clear. But a difficulty arises if the accused happens to weigh the same as he did five minutes before, so nearly at least as can be detected by a pair of heavy wooden scales which would hardly turn within an ounce or two. This embarrassing possibility has in fact perplexed the Hindoo lawyers not a little. One learned pundit says, "He is guilty, unless he goes right up!" A second suggests, "Weigh him again!" A third distinguishes with subtlety, "If he weighs the same he is guilty, but not so guilty as if he had gone right down!" The one only interpretation that never occurs to any of them is, that sin may be an imponderable. We may smile at the Hindoo way of striking a moral balance, but it should be remembered that a similar practice, probably a survival from the same original Aryan rite, was kept up in England within the last century. In 1759, near Aylesbury, a woman who could not get her spinning-wheel to go round, and naturally concluded that it had been bewitched, charged one Susannah Haynokes with being the witch. At this Susannah's husband was indignant, and demanded that his wife should be allowed to clear herself by the customary ordeal of weighing. So they took her to the parish church, stripped her to her under

garments, and weighed her against the church Bible; she outweighed it, and went home in triumph. Here the metaphor of weighing is worked in the opposite way to that in India, but it is quite as intelligible, and not a whit the worse for practical purposes. For yet another case, how an old magical process may be afterward transformed by bringing in the religious sanction, we may look at the ancient classic sieve and shears, the sieve being suspended by sticking the points of the open shears into the rim, and the handles of the shears balanced on the forefingers of the holders. To discover a thief, or a lover, all that was required was to call over all suspected names, till the instrument turned at the right one. In the course of history, this childish divining-ordeal came to be Christianized into the key and Bible; the key, of course, to open the secret, the Bible to supply the test of truth. For a thief-ordeal, the proper mode is to tie in the key at the verse of the 50th Psalm, "When thou sawest a thief, then thou consentedst with him;" and then, when the names are called over, at the name of the guilty one the instrument makes its sign by swerving or turning in the holders' hands. This is interesting, as being almost the only ordeal which survives in common use in England; it may be met with in many an out-of-the-way farmhouse. It is some years since English rustics have dared to "swim" a witch, that is, to put in practice the ancient water-ordeal, which our folk-lore remembers in its most archaic Aryan form. Its essential principle is as plainly magical as any: the water, being set to make the trial, shows its decision by rejecting the guilty, who accordingly comes up to the surface. Our ancestors, who did not seize the distinction between weight and specific gravity, used to wonder at the supernatural power with which the water would heave up a wicked fellow, even if he weighed sixteen stone.

Mediæval ordeals, by water or fire, by touch of the corpse, or by wager of battle, have fallen to mere curiosities of literature, and it is needless to dwell here on their well-known picturesque details, or to repeat the liturgies of prayer or malediction said or sung by the consecrating priests. It is not by such accompanying formulas, but by the intention of the act itself, that we must estimate the real position of the religious element in it. Nowhere is this so strong as in what may be called the ordeal by miracle, where the innocent by divine help walks over the nine red-hot ploughshares, or carries the red-hot iron bar in his hand, or drinks a dose of deadly poison, and is none the worse for it; or, in the opposite way, where the draught of harmless water, cursed or consecrated by the priests, will bring, within a few days, dire disease on him or her who, being guilty, has dared to drink of it.

Looking at the subject from the statesman's point of view, the survey of the ordeals of all nations and ages enables us to judge with some certainty what their practical effect has been for evil or good.

Their basis being mere delusive imagination, when honestly administered, their being right or wrong has been matter of mere accident. It would, however, be a mistake to suppose that fair-play ever generally prevailed in the administration of ordeals. As is well known, they have always been engines of political power in the hands of unscrupulous priests and chiefs. Often it was unnecessary even to cheat, when the arbiter had it at his pleasure to administer either a harmless ordeal like drinking cursed water, or a deadly ordeal by a dose of aconite or physostigma. When it comes to sheer cheating, nothing can be more atrocious than this poison-ordeal. In West Africa, where the Calabar bean is used, the administerers can give the accused a dose which will make him sick, and so prove his innocence, or they can give him enough to prove him guilty, and murder him in the very act of proof; when we consider that over a great part of that great continent this and similar drugs usually determine the destiny of people inconvenient to the fetich-man and the chief—the constituted authorities of church and state—we see before us one efficient cause of the unprogressive character of African society. The famed ordeal by red-hot iron, also, has been a palpable swindle in the hands of the authorities. In India and Arabia the test is to lick the iron, which will burn the guilty tongue but not the innocent. Now, no doubt the judges know the secret that innocent and guilty alike can lick a white-hot iron with impunity, as any blacksmith will do, and as I have done myself, the layer of vapor in a spheroidal state preventing any chemical contact with the skin. As for the walking over red-hot ploughshares, or carrying a red-hot iron bar three paces in the palm of the hand, its fraudulent nature fits with the fact that the ecclesiastics who administered it took their precautions against close approach of spectators much more carefully than the jugglers do who handle the red-hot bars and walk over the ploughshares nowadays; and, moreover, any list of cases will show how inevitably the friend of the Church got off, while the man on the wrong side was sure to "lose his cause and burn his fingers." Remembering how Queen Emma in the story, with uplifted eyes, walked over the ploughshares without knowing it, and then asked when the trial was to begin, and how, after this triumphant issue, one-and-twenty manors were settled on the bishopric and church of Winchester, it may be inferred with some probability that in such cases the glowing ploughshares glowed with nothing more dangerous than daubs of red paint.

Almost the only effect of ordeals which can be looked upon as beneficial to society is, that the belief in their efficacy has done something to deter the credulous from crime, and still more often has led the guilty to betray himself by his own terrified imagination. Visitors to Rome know the great round marble mask called the Bocca della Verità. It is but the sink of an old drain; but many a frightened knave has shrunk from the test of putting his hand into its open

"mouth of truth" and taking oath of his innocence, lest it should really close on him as tradition says it does on the forsworn. The ordeal by the mouthful of food is still popular in Southern Asia for its practical effectiveness: the thief in the household, his mouth dry with nervous terror, fails to masticate or swallow fairly the grains of rice. So in old England, the culprit may have failed to swallow the consecrated cor-snæd, or trial-slice of bread or cheese; it stuck in his throat, as in Earl Godwin's in the story. To this day the formula, "May this mouthful choke me if I am not speaking the truth!" keeps up the memory of the official ordeal. Not less effective is the ordeal by curse, still used in Russia to detect a thief. The *babushka*, or local witch, stands with a vessel of water before her in the midst of the assembled household, and makes bread-pills to drop in, saying to each in order, "Ivan Ivanoff, if you are guilty, as this ball falls to the bottom, so your soul will fall into hell." But this is more than any common Russian will face, and the rule is that the culprit confesses at sight. This is the best that can be said for ordeals. Under their most favorable aspect, they are useful delusions or pious frauds. At worst they are those wickedest of human deeds, crimes disguised behind the mask of justice. Shall we wonder that the world, slowly trying its institutions by the experience of ages, has at last come to the stage of casting out the judicial ordeal; or shall we rather wonder at the constitution of the human mind, which for so many ages has set up the creations of delusive fancy to hold sway over a world of facts?

From the ordeal we pass to the oath. The oath, for purposes of classification, may be best defined as an asseveration made under superhuman penalty, such penalty being (as in the ordeal) either magical or religious in its nature, or both combined. Here, then, we distinguish the oath from the mere declaration, or promise, or covenant, however formal. For example, the covenant by grasping hands is not in itself an oath, nor is even that wide-spread ancient ceremony of entering into a bond of brotherhood by the two parties mixing drops of their blood, or tasting each other's. This latter rite, though often called an oath, can under this definition be only reckoned as a solemn compact. But when a Galla of Abyssinia sits down over a pit covered over with a hide, imprecating that he may fall into a pit if he breaks his word, or when in our police-courts we make a Chinaman swear by taking an earthen saucer and breaking it on the rail in front of the witness-box, signifying, as the interpreter then puts it in words, "If you do not tell the truth, your soul will be cracked like this saucer," we have here two full oaths, of which the penalty, magical or religious, is shown in pantomime before us. By-the-way, the English judges who authorized this last sensational ceremony must have believed that they were calling on a Chinaman to take a judicial oath after the manner of his own country; but they acted under

a mistake, for in fact the Chinese use no oaths at all in their law-courts. Now, we have to distinguish these real oaths from mere asseverations, in which emphatic terms, or descriptive gestures, are introduced merely for the purpose of showing the strength of resolve in the declarer's mind. Where, then, does the difference lie between the two? It is to be found in the incurring of supernatural penalty. There would be no difficulty at all in clearing up the question, were it not that theologians have set up a distinction between oaths of imprecation and oaths of witness. Such subtilties, however, looked at from a practical point of view, are seen to be casuistic cobwebs which a touch of the rough broom of common-sense will sweep away. The practical question is this: does the swearer mean that by going through the ceremony he brings on himself, if he breaks faith, some special magic harm, or divine displeasure and punishment? If so, the oath is practically imprecatory; if not, it is futile, wanting the very sanction which gives it legal value. It does not matter whether the imprecation is stated or only implied. When a Bedouin picks up a straw, and swears by him who made it grow and wither, there is no need to accompany this with a homily on the fate of the perjured. This reticence is so usual in the world, that as often as not we have to go outside the actual formula and ceremony to learn what their full intention is.

Let us now examine some typical forms of oath. The rude natives of New Guinea swear by the sun, or by a certain mountain, or by a weapon, that the sun may burn them, or the mountain crush them, or the weapon wound them, if they lie. The even ruder savages of the Brazilian forests, to confirm their words, raise the hand over the head or thrust it into their hair, or they will touch the points of their weapons. These two accounts of savage ceremony introduce us to customs well known to nations of higher culture. The raising of the hand toward the sky seems to mean here what it does elsewhere. It is in gesture calling on the heaven-god to smite the perjurer with his thunderbolt. The touching of the head, again, carries its meaning among these Brazilians almost as plainly as in Africa, where we find men swearing by their heads or limbs, in the belief that they would wither if forsworn; or, as when among the Old Prussians a man would lay his right hand on his own neck, and his left on the holy oak, saying, "May Perkun (the thunder-god) destroy me!" As to swearing by weapons, another graphic instance of its original meaning comes from Aracan, where the witness swearing to speak the truth takes in his hand a musket, a sword, a spear, a tiger's tusk, a crocodile's tooth, and a thunderbolt (that is, of course, a stone celt). The oath by the weapon not only lasted on through classic ages, but remained so common in Christendom that it was expressly forbidden by a synod; even in the seventeenth century, to swear on the sword (like Hamlet's friends in the ghost-scene) was still a legal oath in Holstein. As for

the holding up the hand to invoke the personal divine sky, the successor of this primitive gesture remains to this day among the chief acts in the solemn oaths of European nations.

It could scarcely be shown more clearly with what childlike imagination the savage conceives that a symbolic action, such as touching his head or his spear, will somehow pass into reality. In connection with this group of oaths, we can carry yet a step further the illustration of the way men's minds work in this primitive stage of association of ideas. One of the accounts from New Guinea is that the swearer, holding up an arrow, calls on Heaven to punish him if he lies; but by turning the arrow the other way the oath can be neutralized. This is magic all over. What one symbol can do, the reverse symbol can undo. True to the laws of primitive magical reasoning, uncultured men elsewhere still carry on the symbolic reversal of their oaths. An Abyssinian chief, who had sworn an oath he disliked, has been seen to scrape it off his tongue and spit it out. There are still places in Germany where the false witness reckons to escape the spiritual consequences of perjury by crooking one finger, to make it, I suppose, not a straight but a crooked oath, or he puts his left hand to his side to neutralize what the right hand is doing. Here is the idea of our "over the left;" but so far as I know this has come down with us to mere schoolboy's shuffling.

It has just been noticed that the arsenal of deadly weapons by which the natives of Aracan swear, includes a tiger's tusk and a crocodile's tooth. This leads us to a group of instructive rites belonging to Central and North Asia. Probably to this day there may be seen in Russian law-courts in Siberia the oath on the bear's head. When an Ostiak is to be sworn a bear's head is brought into court, and the man makes believe to bite at it, calling on the bear to devour him in like manner if he does not tell the truth. Now, the meaning of this act goes beyond magic and into religion, for we are here in the region of bear-worship, among people who believe that this wise and divine beast knows what goes on, and will come and punish them. Nor need one wonder at this, for the idea that the bear will hear and come if called on is familiar to German mythology. I was interested to find it still in survival in Switzerland a few years ago, when a peasant-woman, whom a mischievous little English boy had irritated beyond endurance, pronounced the ancient awful imprecation on him, "The bear take thee!" (der Bär nimm dich!) Among the hill-tribes of India a tiger's skin is sworn on in the same sense as the bear's head among the Ostiaks. Rivers, again, which to the savage and barbarian are intelligent and personal divinities, are sworn by in strong belief that their waters will punish him who takes their name in vain. We can understand why Homeric heroes swore by the rivers, when we hear still among Hindoos how the sacred Ganges will take vengeance sure and terrible on the children

of the perjurer. It is with the same personification, the same fear of impending chastisement from the outraged deity, that savage and barbaric men have sworn by sky or sun. Thus the Huron Indian would say in making solemn promise, "Heaven hears what we do this day!" and the Tunguz, brandishing a knife before the sun, would say, "If I lie, may the sun plunge sickness into my entrails like this knife." We have but to rise one stage higher in religious ideas to reach the type of the famous Roman oaths by Jupiter, the heaven-god. He who swore held in his hand a stone, praying that, if he knowingly deceived, others might be safe in their countries and laws, their holy places and their tombs, but he alone might be cast out, as this stone now—and he flung it from him. Even more impressive was the great treaty-oath, where the *pater patratus*, holding the sacred flint that symbolized the thunderbolt, called on Jove that if by public counsel or wicked fraud the Romans should break the treaty first—"In that day, O Jove, smite thou the Roman people as I here to-day shall smite this swine, and smite the heavier as thou art the stronger!" So saying, he slew the victim with the sacred stone.

These various examples may be taken as showing the nature and meaning of such oaths as belong to the lower stages of civilization. Their binding power is that of curses, that the perjurer may be visited by mishap, disease, death. But at a higher stage of culture, where the gods are ceasing to be divine natural objects like the Tiber or Ganges, or the sun or sky, but are passing into the glorified human or heroic stage, like Apollo or Venus, there comes into view a milder kind of oath, where the man enters into fealty with the god, whom he asks to favor or preserve him on condition of his keeping troth. Thus, while the proceeding is still an oath with a penalty, this penalty now lies in the perjurer's forfeiting the divine favor. To this milder form, which we may conveniently call the "oath of conditional favor," belong such classic phrases as "So may the gods love me!" (*Ita me Dii ament!*), "As I wish the gods to be propitious to me!" (*Ita mihi Deos velim propitios*). I call attention to this class of oaths, of which we shall presently meet with a remarkable example nearer home. We have now to take into consideration a movement of far larger scope.

Returning to the great first-mentioned class of savage and barbaric oaths, sworn by gestures or weapons, or by invocation of divine beasts, or rivers, or greater Nature-deities—the question now to be asked is, What is the nature of the penalties? It is, that the perjurer may be withered by disease, wounded, drowned, smitten by the thunderbolt, etc., all these being temporal, visible punishments. The state of belief to which the whole class belong is that explicitly described among the natives of the Tonga Islands, where oaths were received on the declared ground that the gods would punish the false-swearer here on earth. A name is wanted to denote this class of

oaths, belonging especially to the lower culture; let us call them "mundane oaths." Now, it is at a point above the savage level in culture that the thought first comes in of the perjurer being punished in a world beyond the grave. This was a conception familiar to the Egyptians in their remotely ancient civilization. It was at home among the old Homeric Greeks, as when Agamemnon, swearing his mighty oaths, calls to witness, not only Father Zeus, and the all-seeing sun, and the rivers, and earth, but also the Erinnys who down below chastise the souls of the dead, whosoever shall have been forsworn. Not less plainly is it written in the ancient Hindoo "Laws of Manu"—"A man of understanding shall swear no false oath even in a trifling matter, for he who swears a false oath goes hereafter and here to destruction." To this higher stage of culture, then, belongs the introduction of the new "post-mundane" element into oaths. For ages afterward nations might still use either kind, or combine them by adding the penalty after death to that in life. But in the later course of history there comes plainly into view a tendency to subordinate the old mundane oath, and at last to suppress it altogether. How this came to pass is plain on the face of the matter. It was simply the result of accumulated experience. The continual comparison of opinions with facts could not but force observant minds to admit that a man might swear falsely on sword's edge or spear's point, and yet die with a whole skin; that bears and tigers were not to be depended on to choose perjurers for their victims, and that in fact the correspondence between the imprecation and the event was not real, but only ideal. How judgment by real results thus shaped itself in men's minds we may see by the way it came to public utterance in classic times, nowhere put more cogently than in the famous dialogue in the "Clouds" of Aristophanes. The old farmer Strepsiades asks, "Whence comes the blazing thunderbolt that Zeus hurls at the perjured?" "You fool," replies the Socrates of the play, "you smack of old Kronos's times—if Zeus smote perjurers, wouldn't he have been down on those awful fellows Simon, and Kleonymos, and Theoros? Why, what Zeus does with his bolt is to smite his own temple, and the heights of Sunium, and the tall oaks! Do you mean to say that an oak-tree can commit perjury?" What is said here in chaff full many a reasonable man in the old days must have said to himself in the soberest earnest, and, once said or thought, but one result could come of it—the result which history shows us did come. The venue of the judicial oath was gradually changed, till the later kind, with its penalties transferred from earth to the region of departed souls, remained practically in possession of the field.

As a point in the science of culture, which has hitherto been scarcely if at all observed, I am anxious to call attention to the historical stratification of judicial oaths, from the lowest stratum of mundane oaths belonging to savage or barbaric times, to the highest

stratum of post-mundane oaths such as obtain among modern civilized nations. Roughly, the development in the course of ages may be expressed in the following two classifications:

Mundane Mixed Post-Mundane	} Oaths,	{	Curse. Conditional Favor. Judgment.

Though these two series only partly coincide in history, they so far fit that the judicial oaths of the lower culture belong to the class of mundane curse, while those of the higher culture in general belong to that of post-mundane judgment. Anthropologically, this is the most special new view I have here to bring forward. It forms part of a wider generalization, belonging at once to the science of morals and the science of religion. But, rather than open out the subject into this too wide field, we may do well to fix it in our minds by tracing a curious historical point in the legal customs of our own country. Every one knows that the modes of administering a judicial oath in Scotland and in England are not the same. In Scotland, where the witness holds up his hand toward heaven, and swears to tell the truth as he shall answer to God at the day of judgment, we have before us the most explicit possible example of a post-mundane oath framed on Christian lines. In contrasting this with the English judicial oath, we first notice that our acted ceremony consists commonly in taking a New Testament in the hand and kissing it. Thus, unlike the Scotch oath, the English oath is sworn on a *halidome* (Anglo-Saxon, *hâligdôm;* German, *heiligthum*), a holy or sacred object. Many writers have fallen into confusion about this word, mystifying it into sacred judgment or "holy doom;" but it is a perfectly straightforward term for a sanctuary or relic, as "On tham haligdome swerian"—to swear by the relic. Now, this custom of swearing on a halidome belongs to far pre-Christian antiquity, one famous example being when Hannibal, then a lad of nine years old, was brought by his father to the altar and made to swear, by touching the sacred things (*tactis sacris*), that when he grew up he would be the enemy of Rome. In classical antiquity the sacred objects were especially the images and altars of the gods, as it is put in a scene in Plautus, "Touch this altar of Venus!" The man answers, "I touch it," and then he is sworn. When this ancient rite came into use in early Christian England, the object touched might be the altar itself, or a relic-shrine like that which Harold is touching with his right forefinger in the famous scene in the Bayeux tapestry, or it might be a missal, or a book of the gospels. In modern England a copy of the New Testament has become the recognized halidome on which oaths are taken, and the practice of kissing it has almost supplanted the older and more general custom of touching it with the hand.

Next, our attention must be called to the remarkable formula in which (in England, not in Scotland) the invocation of the Deity is

made, "So help me God!" or "So help you God!" Many a modern Englishman puzzles over this obscure form of words. When the question is asked what the meaning of the oath is, the official interpretation practically comes to saying that it means the same as the Scotch oath. But neither by act nor word does it convey this meaning. So obvious is the discrepancy between what is considered to be meant and what is actually done and said, that Paley, remarking on the different forms of swearing in different countries, does not scruple to say that they are "in no country in the world, I believe, worse contrived either to convey the meaning, or impress the obligation of an oath, than in our own."

This remark of Paley's aptly illustrates a principle of the science of culture which cannot be too strongly impressed on the minds of all who study the institutions of their own or any other age. People often talk of mystic formulas and mystic ceremonies. But, the more we study civilization in its earlier stages, the more we shall find that formulas and ceremonies, both in law and in religion, are as purposeful and business-like as can be, if only we get at them anywhere near their origin. What happens afterward is this, that, while men's thoughts and wants gradually change, the old phrases and ceremonies are kept up by natural conservatism, so that they become less and less appropriate, and then, as their meaning falls away, its place is apt to be filled up with mystery. Applying this principle to the English-oath formula, we ask what and where it originally was. It was Teutonic-Scandinavian, for, though corresponding formulas are known in Latin (*Ita me adjuvet Deus*) and in Old French (*Ce m'ait Diex*, etc.), these are shown by their comparatively recent dates to be mere translations of the Germanic originals. Now, although ancient English and German records fail to give the early history of the phrase, this want is fortunately supplied by a document preserved in Iceland. Some while after the settlement of the island by the Northmen, but long before their conversion to Christianity, the settlers felt the urgent need of a code of laws, and accordingly Ulfliot went to Norway for three years to Thorleif the Wise, who imparted to him his legal lore. Ulfliot went to Norway A. D. 925, so that the form of judicial oath he authorized, and which was at a later time put on record in the Icelandic Landnâmabôk, may be taken as good and old in Norse law. Its pre-Christian character is, indeed, obvious from its tenor. The halidome on which it was sworn was a metal arm-ring, which was kept by the godhi or priest, who reddened it with the blood of the ox sacrificed, and the swearer touching it said, in words that are still half English: "Name I to witness that I take oath by the ring, law-oath, so help me Frey, and Niördh, and almighty Thor (hialpi mer svâ Freyr, ok Niördhr, ok hinn almâttki Âss) as I shall this suit follow or defend, or witness bear or verdict or doom, as I wit rightest and soothest and most lawfully," etc. Here, then, we have the full

and intelligible formula which must very nearly represent that of which we keep a mutilated fragment in our English oath. So close is the connection, that two of the gods referred to, Frey and Thor (who is described as the almighty god), are the old English gods whose names we commemorate in Friday and Thursday. The formula belongs, with the classic ones lately spoken of, to the class of oaths of conditional favor, "*so* help me *as* I shall do rightly," while Frey and Niördh are gods whom a Norse warrior would ask for earthly help, but who would scarcely concern themselves with his soul after death. It is likely that the swearer was not indeed unmindful of what the skalds sang of Naströnd, the strand of corpses, that loathly house arched of the bodies of huge serpents, whose heads, turned inward, dripped venom on the perjurers and murderers within. But the primary formula is, as I have said, that of the oath of conditional favor, not of judgment. With the constituents of the modern English oath now fairly before us, we see that its incoherence, as usual in such cases, has an historical interpretation. What English law has done is to transplant from archaic fetich-worship the ceremony of the halidome or consecrated object, and to combine with this one-half of a pre-Christian formula of conditional favor, without the second half which made sense of it. Considering that to this combination is attached a theological interpretation which is neither implied in act nor word, we cannot wonder if in the popular mind a certain amount of obscurity, not to say mystery, surrounds the whole transaction. Nevertheless, we may well deprecate any attempt to patch up into Scotch distinctness and consistency the old formula, which will probably last untouched so long as judicial oaths shall remain in use in England.

Being in the midst of this subject, it may not be amiss to say a few words upon old and new ideas as to the administration of oaths to little children. The Canon Law expressly forbade the exacting of an oath from children under fourteen—*pueri ante annos XIV non cogantur jurare.* This prohibition is derived from yet earlier law. The rough old Norsemen would not take oaths from children, as comes out so quaintly in the *saga* of Baldur, where the goddess made all the beasts and birds and trees swear they would not harm him, but the little mistletoe only she craved no oath from, for she thought it was too young. Admitting the necessity of taking children's evidence somehow, the question is how best to do it. In England it must be done on oath, and for this end there has arisen a custom in our courts of putting the child through an inquisition as to the theological consequences of perjury, so as usually to extract from it a well-known definition which the stiffest theologian will not stand to for a moment if put straight to him, but which is looked upon as a proper means for binding the conscience of a little child.[1] Moreover, children

[1] Two illustrative cases are given me by a friend learned in the law. In court lately, a little girl was asked the usual preliminary question as to the consequence of swearing

in decent families learn to answer plain questions some years before they learn to swear, and material evidence is often lost by the child not having been taught beforehand the proper answers to make when questioned as to the nature of an oath. I heard of a case only lately, which was expected to lead to a committal on a charge of murder, and where an important point rested on the evidence of a young lad who was, to all appearance, truthful, but who did not satisfy the bench that he understood the nature of an oath. Those in whom the ceremony of swearing a child arouses the feeling of physical repugnance that it does in myself, may learn with interest a fact as yet little known in England, and which sufficiently justifies my bringing forward the subject. Hearing that there was something to be learned from Germany, I applied to the eminent jurist, Dr. Gneist, of Berlin, and hear from him that under the new German rules of procedure, which are expected shortly to come into force, the evidence of children under sixteen may be received without oath, at the discretion of the judge. In these days there is a simple rule which an Englishman will do well to act up to, and that is, "Don't be beaten by a German!" Let us live in the heartiest fellowship with the Germans, and never let them get ahead of us if we can help it. In this matter of children's legal evidence, they are fairly leaving us behind, by introducing a plan which is at once more humane and more effective than ours.

If, now, looking at the subject as one of practical sociology, we consider what place the legal oath has filled in savage, barbaric, and civilized life, we must adjudge to it altogether higher value than to the ordeal. At certain stages of culture it has been one of the great forces of society. There was a time when Lycurgus could tell the men of Athens that the oath was the very bond that held the democracy together. There was a time when, as Montesquieu insists, an oath was so binding on the minds of the Romans, that for its observance they would do more than even patriotism or love of glory could draw them to. In our own day, its practical binding power is unmistakable over the consciences of a numerous intermediate class of witnesses, those who are neither truthful nor quite reckless, who are without the honesty which makes a good man's oath superfluous, who will indeed lie solemnly and circumstantially, but are somewhat restrained from perjury by the fear of being, as the old English saying has it, "once forsworn, ever forlorn." Though the hold thus given is far weaker than is popularly fancied, it has from time to time led

falsely, and answered in due form, "Please, sir, I should go to burning hell!" Unluckily, however, the unusual question was then put, how she knew that? which brought the reply, "Oh, please, another girl outside told me I was to say so!" It is bar tradition, though there may be no record in print, that years ago the most sarcastic of English judges put the whole matter in a nutshell. The question having been asked of a child witness, if she knew what would become of her when she died, she answered simply, "Don't know, sir!" whereupon the judge said, "Well, gentlemen, no more do I know—but the child's evidence cannot be taken."

legislators to use oaths, not merely in special and solemn matters, but as means of securing honesty in the details of public business. When this has been done, the consequences to public morals have been disastrous. There is no need to hunt up ancient or foreign proofs of this, seeing how conspicuous an instance is the state of England early in the present century, while it was still, as a contemporary writer called it, "a land of oaths," and the professional perjurer plied a thriving trade. A single illustration will suffice, taken from the valuable treatise on Oaths, published in 1834, by the Rev. James Endell Tyler: "During the continuance of the former system of custom-house oaths, there were houses of resort where persons were always to be found ready at a moment's warning to take any oath required; the signal of the business for which they were needed was this inquiry, 'Any damned soul here?'" Nowadays this enormous excess of public oaths has been much cut down, and with the best results. Yet it must be evident to students of sociology that the world will not stop short at this point. The wider question is coming into view, What effect is produced on the every-day standard of truthfulness by the doctrine that fraudulent lying is in itself a minor offense, but is converted into an awful crime by the addition of a ceremony and a formula? It is an easily-stated problem in moral arithmetic; on the credit side, Government is able to tighten with an extra screw the consciences of a shaky class of witnesses and public officers; on the debit side, the current value of a man's word is correspondingly depreciated through the whole range of public and private business. As a mere sober student of social causes and effects, following along history the tendencies of opinion, I cannot doubt for a moment how the public mind must act on this problem. I simply predict that where the judicial ordeal is already gone, there the judicial oath will sooner or later follow. Not only do symptoms of the coming change appear from year to year, but its greatest determining cause is unfolding itself day by day before observant eyes, a sight such as neither we nor our fathers ever saw before.

How has it come to pass that the sense of the sanctity of intellectual truth, and the craving after its full and free possession, are so mastering the modern educated mind? This is not a mystery hard to unravel. Can any fail to see how in these latter years the methods of scientific thought have come forth from the laboratory and the museum to claim their powers over the whole range of history and philosophy, of politics and morals? Truth in thought is fast spreading its wide waves through the outside world. Of intellectual truthfulness, truthfulness in word and act is the outward manifestation. In all modern philosophy there is no principle more fertile than the doctrine so plainly set forth by Herbert Spencer—that truth means bringing our minds into accurate matching with the realities in and around us; so that both intellectual and moral truth are bound up together in

that vast process of evolution whereby man is gradually brought into fuller harmony with the universe he inhabits. There need, then, be no fear that the falling away of such artificial crutches as those whose history I have here been tracing should leave public truth maimed and halting. Upheld by the perfect fitting of the inner mind to the outer world, the progress of truth will be firmer and more majestic than in the ancient days. If, in time to come, the grand old disputation before King Darius were to be reënacted, to decide again the question, "What is the strongest of all things?" it would be said, as then, that "Truth abides, and is strong for evermore, living and conquering from age to age." And the people as of old would say again with one voice, "Truth is great, and prevails!" [1]—*Advance-sheets of Macmillan's Magazine.*

THE CHROMIS PATER-FAMILIAS.

By Dr. LORTET.

UP to the present we know but a small number of fishes which hatch their eggs and bring up their young in the cavity of the mouth or among the gills. Agassiz, during his voyage on the Amazonas, discovered one species. Afterward there was brought from China the macropod, the singular habits of which are now known to all the world. All these species belong to the great group of the *Labyrinthobranchiata;* and Agassiz supposes that the fishes of this order only can hatch their eggs in so abnormal a manner, thanks to the branchial pockets which allow of the eggs being easily kept in place. But the *Chromis*, of which we give a faithful representation, proves the assertion of Agassiz to be erroneous. The *Chromis pater-familias* has the gills disposed in simple laminæ; it is unprovided with any special apparatus for retaining the eggs or the young ones, and yet it brings up about 200 young in the mouth and gills. It is always the male that performs these functions of incubation. After the female has deposited the eggs in a depression of the sand or between the tufts of reeds, the male approaches and takes them by inhalation into the cavity of the mouth. From there some movement, the mechanism of which we have not been able to observe, sends them between the leaflets of the gills. The pressure exerted on the eggs by the branchial laminæ suffices to keep them in place. There, in the midst of the organs of respiration, the eggs undergo all their metamorphoses. The young ones grow rapidly, and soon appear much inconvenienced in their narrow prison. They leave it, not by the gills but through the opening by which the bronchial cavity communicates with the

[1] 1 Esdras iv. 41: μεγάλη ἡ ἀλήθεια, καὶ ὑπερισχύει—*Magnas est veritas, et prævalet.*

mouth. Here they remain in great number, pressed against one another like the seeds of a pomegranate. The animal's mouth becomes so distended by the presence of this numerous progeny that actually the jaws cannot meet. The cheeks are swollen and the animal pre-

CHROMIS PATER-FAMILIAS OF LAKE TIBERIAS.

sents the strangest aspect. Some of the young, arrived at the perfect state, continue to live in the gills. All have the head directed toward the buccal opening of the father, the protecting cavity of which we have not seen them leave even for a moment. Though so numerous,

they hold their ground very firmly, yet how they do so we have not discovered. Neither can we understand how the nursing father avoids swallowing his progeny; we are also ignorant at what period of their life the young ones leave the paternal mouth to live independently.

The *Chromis pater-familias* is 7 inches long by 1¾ inch thick. The teeth are very fine and sharp, disposed in several rows. The snout is obtuse, conical, the upper profile oblique. The nasal prominence is very conspicuous. The caudal fin is almost truncated. The soft rays of the dorsal reach to the beginning of the caudal. The length of the body, including the tail, is 4½ times its thickness. The snout is in length twice the diameter of the orbit. The mouth is slightly oblique, large, as wide as it is long. The teeth are slightly recurved, disposed in three or four rows, tinged with deep yellow at the free end. The first row presents 26 on each side of the upper maxillary. The fins show the number of rays following:

Dorsal	14+11
Anal	3+ 8
Caudal	16
Pectoral	12
Ventral	1+ 5

The lateral line comprises 32 scales disposed 20+12. The scales are cycloidal, their length greater than their breadth; three-fourths of their surface is covered by the succeeding scales. Color, olive-green on the back, barred with blue. The belly has a silvery lustre, with green and blue spots.

I caught this interesting species, with a net, on the 29th of April, 1875, in shallow water full of reeds, on the margin of Lake Tiberias, at a place called Ain-Tin, the ancient Capernaum. There are numerous warm springs there which unite to form a rather considerable stream. It is in these warm waters that the *Chromis* lives. —*La Nature.*

BIGOTRY IN SCIENTIFIC CONTROVERSY.[1]

MANY edifying commonplaces might doubtless be written on the intellectual fermentation, if it may not rather be called confusion of the age. Nor can it be denied that tendencies supposed to have been long ago slain and sepulchred have risen again, and are asserting themselves with a hardihood which our fathers would have deemed impossible. When we find a scientific work—at any rate a work written by an eminent scientific man, and devoted to the dis-

[1] "Lessons from Nature. By St. George Mivart, F. R. S." New York: D. Appleton & Co.

cussion of scientific questions—formally dedicated to a dignitary of the Catholic Church as a vindicator of the rights of conscience (!), we may well ask, not jeeringly but sadly, "What is truth?" We have witnessed of late brilliant progress in various departments of science; but we have also seen attacks made upon the very foundations of science. These onslaughts are increasing in frequency and in boldness. Metaphysicians and ecclesiastics are calling in question the inductive method, impugning the independence of Science, and seeking to reassert over her the authority of "the Church." The battles of the sixteenth century seem about to be repeated. And some, who might claim to be the heirs of Galileo, think it no ignominy to wear the livery of Bellarmin and Caccini.

When we first opened the book which has suggested our present article we fully expected to find an intellectual treat of the highest order: its subject is one on which a most valuable work might well be written, and few living men, indeed, are better qualified to undertake such a task than is Mr. Mivart. Anti-Darwinian polemics we awaited, but such criticism, if conducted on legitimate—that is, on purely scientific—principles, we should be among the first to welcome, well knowing that in any issue Science must be the gainer. Although believing in Evolution, we have never given to the hypothesis commonly known as "Darwinism" more than a qualified and provisional adhesion. While admitting that it has thrown a flood of light over some of the most difficult questions in natural history, and has brought into vital connection a previously incoherent mob of facts, and that it is still a powerful and valuable instrument in the hands of the inquirer, we cannot forget that it has its difficulties. Some of these we have, on former occasions, endeavored to point out. Hence we should cordially recognize any theory which should either supplement the doctrines of "Natural Selection" and "Sexual Selection," or modify them so as to get rid of their drawbacks and shortcomings. Nay, we should be well pleased to find them superseded altogether by a new hypothesis, adapted at once to the phenomena they have explained and the residues and anomalies which they have hitherto left unsolved. Such an hypothesis we thought Mr. Mivart might have produced, or at least have attempted; and the very attempt could scarcely be made, from a legitimate point of view, without leading to valuable results. Never were we more signally disappointed, although in these days the title of a book is often intended to conceal, rather than to reveal, its nature and object. The strange dedication was, in truth, but too ominous of the contents. The work we found was not constructive, but destructive. It consists of a series of attacks upon a number of men who have done good service in different branches of science, such as Darwin, Wallace, Huxley, Tyndall, Galton, Lubbock, Helmholtz, Oscar Schmidt—or who have dealt with methodology, such as Comte, Mill, Spencer, Lewes, etc. The doctrines of

natural selection and sexual selection are indeed discussed, and a desperate effort is made to resuscitate the fast-fading notion of a "great gulf" between man and the lower animals. It is a curious fact that in the old natural history man is supposed to hold, in relation to other animals, a place very similar to that assigned by the Lavoisierian chemistry to oxygen in relation to the remaining elements. Unfortunately, in biology, passion, prejudice, and sophistry, play a more important part than they do in chemistry and physics. The discussion is based upon false principles. We all know the passage in which Mr. Wallace specifies the kind of controversy which alone can be recognized: "As his hypothesis is one which claims acceptance solely as explaining and connecting facts which exist in Nature, he expects facts alone to be brought to disprove it." [1] This method of discussion finds here comparatively little favor. Theories are tested by their supposed moral or religious bearings, or by their agreement with the author's *a priori* views. If we bring facts to prove the existence of reason in animals, we are told that we do not know what reason is; if we find in them evidences of moral life, it is said that we have "not even the faintest conception of what a moral nature is." If we show that they possess language, there follows the ready quirk that we confound emotional language with intellectual. That Mr. Mivart's own views of moral nature and of reason must be correct, no one, of course, is supposed to doubt; nor is the spirit of the argument sounder than its method. The author speaks, not as a judge calmly weighing the arguments on either side, and anxious merely that the truth should be ascertained, but as a passionate and eager prosecuting counsel, or rather as a *procureur du roi* (king's attorney), skillfully bringing forward every circumstance, every point—actual or inferred, relevant or irrelevant—which may in any wise damage the defendants, and with equal dexterity concealing whatsoever might tell in their favor. Deep personal hatred toward the "Agnostics" and their doctrines—the *odium theologicum* in its most malignant form—pervades the entire book. Mr. Mivart may doubtless be able to meet Mr. Darwin, Mr. Lewes, Mr. Spencer, or Dr. Huxley, on neutral ground or in private life, on terms of ordinary courtesy; but it is because the man is better and greater than his book. We find here nothing of that fine manly spirit expressed in the old adage, "Plato is my friend, but truth is more my friend." On the contrary, there is one passage in which Mr. Mivart almost seems to apologize for having, on some former occasion, spoken of Mr. Darwin with too much courtesy. For this he has now atoned to an extent almost ludicrous. We should not have felt in the least surprised had we found it proved—of course by strictly metaphysical arguments—that the author of the "Origin of Species" is the veritable transgressor who—

[1] "Contributions to the Theory of Natural Selection," p. 13.

"Filled the butchers' shops with large blue flies,"

or who—

"With foul earthquakes ravaged the Caracas,
And raised the price of sugars and tobaccos."

Suppose, in all sober sadness, an inquirer knowing nothing more of Darwin than what he might learn out of "Lessons from Nature." Would he not go away with the impression that our great English naturalist had done little beyond launching a "puerile hypothesis," and had played a very unimportant—and, if anything, rather injurious—part in the development of biological science? Yet every candid critic must admit that, were the theory of natural selection superseded to-morrow, to Darwin would still belong the merit of effecting in natural history a transformation as signal as that wrought in astronomy by Galileo, Copernicus, and Kepler, or in chemistry by Lavoisier; of bestowing upon zoölogy and botany a definite purpose and a direction for research such as before were wanting. His works would still remain a treasury of observations and of suggestions, and the impulse he has given to the science would never die away. In England, Germany, America, naturalists have sprung up as if by magic in obedience to his spell, and Mr. Mivart himself can hardly be excluded from their number.

We need scarcely add that a critic unjust to persons will not be much more trustworthy as regards their discoveries and their doctrines. The evidence in favor of natural selection—and indeed of evolution altogether—is strictly cumulative, and as such, whatever weight it may carry to the patient and dispassionate inquirer, it is peculiarly open to the attacks of an opponent at one skillful and unscrupulous. We do not, of course, mean to accuse Mr. Mivart of deliberate unscrupulousness. We all know the words—in themselves literally reeking with hypocrisy—in which "the Church" pronounced sentence of death on Giordano Bruno: "*Ut quam clementissime et citra sanguinis effusionem puniretur*" (Let him be punished as leniently as may be, and without shedding blood). Yet even on that occasion we should be reluctant to declare that the judges were sinning against better light and knowledge. Just so here: Mr. Mivart doubtless believes and feels what he says, and considers his own line of criticism fair and honorable. We know that man is an adept in self-delusion, and of all men the metaphysician who has cultivated the art *s'égarer avec méthode* (of going astray methodically) is most likely to go unconsciously astray.

We come now to a most painful subject, which, indeed, we would gladly pass over were not its consideration absolutely imperative. Mr. Mivart complains that in one particular instance Mr. Darwin departs from his ordinary courtesy to opponents. We are therefore justified in assuming that he regards courtesy to opponents as a duty —at least in others. Bearing in mind this circumstance, we turn to

page 144, and read: "It is in one respect a calamity of our time and country that unbelievers, instead of, as in France, honestly avowing their sentiments, disguise them by studious reticence—as Mr. Darwin at first studiously disguised his views as to the bestiality (!) of man, and as the late Mr. Mill silently allowed himself to be represented to the public as a thorough believer in God." Along with this passage we take the remarks on "Mr. Winwood Reade, a friend and ardent disciple of Mr. Darwin," and on the teachings of "our English physical expositors" (pp. 393–395), and then ask whether the author is not, by implication at least, charging Mr. Darwin with atheism? This is the more probable, as we can find no saving clause or limitation guarding against such a construction being put upon these passages. Still, in a charge so grave the accused is entitled to the benefit of the faintest doubt, and Mr. Mivart may therefore claim a verdict of "Not proven." It is time, however, that we came to a full understanding about the foul practice of introducing charges of atheism in scientific controversy. On this subject we beg to offer the following considerations:

1. Charges of "heresy," "infidelity," or "atheism," are beside the question. If a theory in astronomy, in geology, in physics, chemistry, or biology, is in doubt, let it be judged on its own evidence; that is, let it be compared respectively with astronomical, geological, physical, chemical, or biological facts, and, according as it is able or unable to account for and to harmonize such, let it stand or fall. The man who is unable or unwilling to do this convicts himself, from an intellectual point of view, either of impotence or perversity, and should leave controversy to others.

2. Such charges, further, are delusive. Not to speak of the thoroughly-trained scholar, even many of the "half-educated" know that almost every important discovery in science has been denounced by the "*parti prêtre*" (clerical party) as impious, heretical, and atheistic. A yearly volume of the *Quarterly Journal of Science* would not contain the abuse uttered by ecclesiastics against the Copernican theory of the solar system, against the doctrine of a plurality of worlds, the Newtonian view of the universe, the nebular hypothesis, the chronology of modern geologists, etc. Yet all these views, and many more which might be mentioned, were found—when passion had cooled and sober judgment had time to decide—perfectly compatible, not with theism merely, but with Christian revelation. What "the Church" has cursed in one generation, she "assimilates" in the next. What educated man, then, after reviewing the past, can dare to set aside modern theories in such a manner?

3. Such charges are, further, distinctly immoral, and even criminal. All civilized countries brand with ignominy the suitor or the advocate who suborns false witnesses, forges or destroys documents, or corrupts judges and juries. But the controversialist who charges his opponent with atheism stands in a precisely similar position. He

well knows that, although the public might not admit, *totidem verbis* (in so many words), that "whatever an atheist advances must be false," or that "every theory once pronounced atheistic must be erroneous," yet it will practically act as if such propositions were established. Hence by making such charges he fraudulently attempts to steal from the public, through an appeal to their passions, a verdict which he has no hope of obtaining from their reason. Knowing and trading on the extreme animosity with which the heretic, the skeptic, and the atheist are—rightly or wrongly—regarded, he seeks to deprive his opponents of a fair hearing by applying to them these dreaded names. A meaner, a more infamous stratagem can scarcely be conceived. Yet more: it is not the man conscious of the goodness of his cause who fights with such weapons. He who knows that his views are in harmony with facts has nothing to gain by foul play; but if he feels inward misgivings concerning the doctrines which he advocates, or doubts at least the possibility of bringing forward valid arguments in their defense, he may readily, if dishonest enough, seek to blacken the character of an opponent.

We may, therefore, safely and fairly conclude that whosoever in scientific controversy introduces accusations of atheism is, if not knowingly and willfully, still decidedly in the wrong. We are consequently fully justified in shutting his book, and giving judgment against him.

But there is another consideration which here forces itself upon our attention. All writings calculated to bring a man into general "ridicule, hatred, or contempt," are by the law declared to be libelous. Now, it is very questionable if, in England, any accusation is so much calculated to bring a man into "hatred and contempt" as a charge of atheism or "materialism," however ill-founded it may be. Surely therefore such charges, whether brought directly or by implication, are libelous, and as such they are more fitted to be dealt with by a criminal court than by reviewers. We should like to see such a case decided, and we believe that the result would be a great improvement in the tone of scientific and semi-scientific controversy.

But even if such accusations should be pronounced not libelous, and if those who resort to them have no legal penalties to dread, there is another tribunal which might interfere. Why should not scientific men, scientific societies, and scientific journals, agree that whosoever in a scientific controversy attempts to get rid of an opponent by raising the cry of atheism should be held to be *ipso facto* an outlaw, and to be no longer entitled to the treatment of a gentleman and a scholar? Nay, why should not other charges affecting the personal character of an opponent be dealt with in a similar manner? We do not, of course, seek to screen the man who can be proved to have suppressed documents, cooked results, or claimed as his own discoveries those which he well knew belonged to another. We refer to

those random charges of dishonesty and mendacity, and those sweeping ascriptions of motive which are unfortunately so common. Thus we have often heard and seen it asserted that the authors of some particular theory were actuated by a desire to disprove the existence of a God, to subvert the Christian religion or some particular form of it, or to injure public morals. To such assertors we would reply: "Prove your charge by evidence, such as would satisfy an impartial court of justice, or take the consequences, which will not be pleasant!" We are here reminded that in the very passage in Mr. Mivart's book (p. 144), in which he comes unpleasantly near charging Mr. Darwin with atheism, he brings forward against the same gentleman something very like an accusation of dishonesty. It is perfectly true that in the "Origin of Species" Mr. Darwin does not pronounce as to whether mankind had or had not been gradually evolved from some lower form of animal life. But reticence is very different from dishonesty. A thinker is not absolutely bound to bring his speculations to light at all; for keeping them back, while he is accumulating and weighing the evidence for and against them, he deserves praise rather than censure. Nay, even for introducing doctrines gradually, as the public are able to bear them, there is certainly authority which Mr. Mivart cannot consistently impugn. Nor must we forget that Mr. Darwin has, from the first, nowise courted publicity for his views. But for the fact that Mr. Wallace was known to be preparing a work of a somewhat similar nature, even the "Origin of Species" might never have seen the light.

There may be persons who will be aggrieved at this expression of our views on the subject of scientific controversies; but if they feel themselves guiltless they may cheerfully exclaim, "Let the galled jade wince." As for those who have actually made the kind of charges we protest against, they have no claim to lenity or forbearance.

Controversies on theories in the various inorganic sciences have been carried on with no little acrimony. But charges of atheism are, at least, banished. Why may not this reform be extended to biology and psychology? Those who cannot treat these subjects from a purely scientific point of view may serve to test the patience of unfortunate reviewers, but they cannot lead us to the truth.—*Extract from Article in the Quarterly Journal of Science.*

LESSONS IN ELECTRICITY.[1]

HOLIDAY LECTURES AT THE ROYAL INSTITUTION.

By Prof. TYNDALL, F. R. S.

IV.

SECTION 17. *History of the Leyden-Jar.*—The next discovery which we have to master throws all former ones into the shade. It was first announced in a letter addressed on the 4th of November, 1745, to Dr. Lieberkühn, of Berlin, by Kleist, a clergyman of Cammin, in Pomerania. By means of a cork, *C*, Fig. 23, he fixed a nail, *N*, in a phial, *G*, into which he had poured a little mercury, spirits, or water, *W*. On electrifying the nail he was able to pass from one room into another with the phial in his hand and to ignite spirits of wine with it. "If," said he, "while it is electrifying I put my finger, or a piece of gold which I hold in my hand, to the nail, I receive a shock which stuns my arms and shoulders."

In the following year Cunæus, of Leyden, made substantially the

Fig. 23.

Fig. 24.

Fig. 25.

same discovery. It caused great wonder and dread, which arose chiefly from the excited imagination. Musschenbroek felt the shock, and declared in a letter to a friend that he would not take a second one for the crown of France. Bleeding at the nose, ardent fever, a heaviness of head which endured for days, were all ascribed to the shock. Boze wished that he might die of it, so that he might enjoy the honour of having his death chronicled in the "Paris Academy of Sciences." Kleist missed the explanation of the phenomenon; while

[1] A course of six lectures, with simple experiments in frictional electricity, before juvenile audiences during the Christmas holidays.

the Leyden philosophers correctly stated the conditions necessary to the success of the experiment. Hence the phial received the name of the Leyden-phial, or Leyden-jar.

The discovery of Kleist and Cunæus excited the most profound interest, and the subject was explored in all directions. Wilson, in 1746, filled a phial partially with water, and plunged it into water, so as to bring the water surfaces, within and without, to the same level. On charging such a phial the strength of the shock was found greater than had been observed before.

Two years subsequently Dr. Watson and Dr. Bevis noticed how the charge grew stronger as the area of the conductor in contact with the outer surface increased. They substituted shot for water inside the jar, and obtained substantially the same effect. Dr. Bevis then coated a plate of glass on both sides with silver-foil, within about an inch of the edge, and obtained from it discharges as strong as those obtained from a phial containing half a pint of water. Finally, Dr. Watson coated his phial inside and out with silver-foil. By these steps the Leyden-jar reached the form which it possesses to-day.

It is easy to repeat the experiment of Dr. Bevis. Procure a glass plate nine inches square; cover it on both sides with tin-foil six inches square. Connect one side with the earth and the other with the machine. Charge and discharge: you obtain a brilliant spark.

In our experiment with the golden fish (Fig. 22), we employed a common form of the Leyden-jar, only with the difference that to get to a sufficient distance from the glass, so as to avoid the attraction of the fish by the jar itself, the knob was placed higher than usual. But, with a good flint-glass tumbler, a piece of tin-foil, and a bit of wire, you can make a jar for yourself. Bad glass, remember, is not rare. In Fig. 24 you have such a jar. *T* is the outer, *T'* the inner coating, reaching to within an inch of the edge of the tumbler *G*. *W* is the bit of wire fastened below by wax, and surmounted by a knob, which may be of metal, or of wax or wood, coated with tin-foil. In charging the jar you connect the outer coating with the earth—say with a gas-pipe or a water-pipe—and present the knob to the conductor of your machine. A few turns will charge the jar. It is discharged by laying one knob of a "discharger" against the outer coating, and causing the other knob to approach the knob of the jar. Before contact, the electricity flies from knob to knob in the form of a spark.

A "discharger" suited to our means and purposes is shown in Fig. 25. *H* is a stick of sealing-wax: *W W* a stout wire bent as in the figure, and ending in the knobs *B B'*. These may be of wax coated with tin-foil. Any other light conducting knobs would of course answer. The insulating handle *H* protects you effectually from the shock.

Sec. 18. *Explanation of the Leyden-Jar.*—The principles of electrical induction with which you are now so familiar will enable

you to thoroughly analyze and understand the action of the Leyden-jar. In charging the jar, the outer coating is connected with the earth and the inner coating with the electrical machine. Let the machine, as usual, be of glass yielding positive electricity. When it is worked the electricity poured into the jar acts inductively across the glass upon the outer coating; attracting its negative and repelling its positive to the earth. Two mutually attractive electric layers are thus in presence of each other, being separated merely by the glass. When the machine is in good order and the glass of the jar is thin, the attraction may be rendered strong enough to perforate the jar.

Franklin saw and announced with clearness the escape of the electricity from the outer coating of the jar. His statement is that, whatever be the quantity of the "electric fire" thrown into the jar, an equal quantity was dislodged from the outside. We have now to prove by actual experiment that this explanation is correct.

Place your Leyden-jar upon a table, and connect the outer coating with your electroscope. There is no divergence of the leaves when electricity is poured into the jar.

But here the outer coating is connected through the table with the earth. Let us cut off this communication by an insulator. Place the jar upon a board supported by warm tumblers, or upon a piece of vulcanized India-rubber cloth, and again connect the outer coating with the electroscope. The moment electricity is communicated to the knob of the jar the leaves of Dutch metal diverge. Detach the wire by your discharger and test the quality of the electricity—it is positive, as theory declares it must be.

Consider now the experiment of Kleist and Cunæus (Fig. 23). You will, I doubt not, penetrate its meaning. You will see that in their case the *hand* formed the outer coating of the jar. When electricity was communicated through the nail to the water within, that electricity acted across the glass inductively upon the hand, attracting the one fluid and repelling the other to the earth.

Again I say, prove all things; and what is here affirmed may be proved by the following beautiful and conclusive experiment: Stand on your board, insulated by its four tumblers; or upon a sheet of gutta-percha, or vulcanized India-rubber. Seize the old Leyden-phial with your left hand, and touch the electroscope with the right, or with a lath or a wire held in the right. When electricity is communicated to the nail, the leaves immediately diverge by the electricity driven from your left hand through your body to the electroscope.

Here the nail may be electrified either by connecting it with the prime conductor of the machine, or by simply rubbing it with an excited glass rod. Indeed, I should prefer your resorting to the simplest and cheapest means in making these experiments.

As a thoughtful and reflective boy you cannot, I think, help wondering at the power which your thorough mastery of the principles

of induction gives you over these wonderful and complicated phenomena. By those principles the various facts of our science are bound together to an organic whole. But we have not yet exhausted the fruitfulness of this principle.

Consider the following problem. Usually we allow the electricity of the outer coating to escape to the earth. Suppose we try to utilize it. Place, then, your jar upon vulcanized India-rubber, and connect its outer coating by a wire with the knob or inner coating of a second jar. What will occur when the first jar is charged? Why, the second one will be charged also by the electricity which has escaped from the outer coating of the first. And suppose you connect the outer coating of the second insulated jar with the inner coating of a third; what occurs? The third jar will obviously be charged with the electricity repelled from the outer coating of the second. Of course, we need not stop here. We may have a long series of insulated jars, the outer coating of each being connected with the inner coating of the next succeeding one. Connect the outer coating of the last jar with the earth, and charge the first jar. You charge thereby the entire series of jars. In this simple way you master practically, and grasp the theory of the celebrated "*cascade battery*" of Franklin, represented in Fig. 26, with coated glass tumblers, *A*, *B*, *C*, *D*,

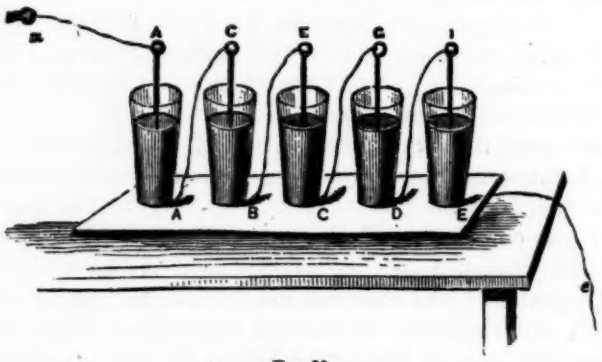

FIG. 26.

and so on. You must see that, before making the experiment, you could really have predicted what would occur. This power of prevision is one of the most striking characteristics of science.

SEC. 19. *Novel Leyden-Jars of the Simplest Form.*—But, possessed of its principles, we can reduce the Leyden-jar to a far simpler form than any hitherto dealt with. Spread a sheet of tin-foil smoothly upon a table, and lay upon the foil a pane of glass, somewhat smaller than the foil in size. Remember that the glass, as usual, must be dry. Stick on to the glass by sealing-wax two loops of narrow silk ribbon, by which the pane may be lifted; and then lay smoothly upon the glass a second sheet of tin-foil, less than the pane in size.

Carry a fine wire from the upper sheet of tin-foil to your electroscope. A little weight will keep the end of the wire attached to the tin-foil.

Rub this weight with your excited glass tube, two or three times if necessary, until you see a slight divergence of the Dutch metal leaves. Or, connecting the weight with the conductor of your machine, turn very carefully until the slight divergence is observed. What is the condition of things here? You have poured, say, positive electricity on to the upper sheet of metal. It will act inductively across the glass upon the under sheet, the positive fluid of which will escape to the earth, leaving the negative behind. You see before your mind's eye two layers holding each other in bondage. Now, take hold of your loops and lift the glass plate, so as to separate the upper tin-foil from the lower. What would you expect to occur? Freed from the grasp of the lower layer, the electricity of the upper one will diffuse itself over the electroscope so promptly and powerfully that, if you are not careful, you will destroy the instrument by the mutual repulsion of its leaves.

Practise this experiment, which is perfectly easy and perfectly beautiful, by lowering and lifting the glass plate, and observing the corresponding rhythmic action of the leaves of the electroscope. The experiment was shown here twelve years ago to boys and girls who are now men and women.

Common tin-plate may be used in this experiment, instead of tin-foil, and a sheet of vulcanized India-rubber instead of the pane of glass. Or, simpler still, for the tin-foil a sheet of common unwarmed foolscap may be employed. Satisfy yourself of this. Spread a *sheet* of foolscap on a table; lay the plate of glass upon it, and spread a *leaf* of foolscap, less than it in size, on the plate of glass. Connect the leaf with the electroscope, and charge it exactly as you charged the tin-foil. On lifting the glass with its leaf of foolscap, the leaves of the electroscope instantly fly apart; on lowering the glass, they again fall together. Abandon the under sheet altogether, and make the table the outer coating; if it be not of very dry wood, or covered by an insulating varnish, you will obtain with it the results obtained with the tin-foil, tin, and foolscap.

The withdrawal of the electricity from the electroscope, by lowering the plate of glass, so as to bring the electricity of the upper coating within the grasp of the lower one, is sometimes called "condensation." The electricity on one plate or sheet was figured as squeezed together, or condensed, by the attraction of the other. A special instrument, called a *condenser*, is constructed by instrument-makers to illustrate the action here explained.

You may readily make a condenser for yourself. Take two circles, *P P'*, Fig. 27, of tin or of sheet-zinc, and support the one, *P'*, by a stick of sealing-wax or glass, *G*; the other, *P*, by a metal stem, connected with the earth. The insulated plate, *P'*, is called the collect-

ing plate; the uninsulated one, *P*, the condensing plate. Connect the collecting plate with your electroscope by the wire, *W*, and bring the condensing plate near it, leaving, however, a thin space of air between them. Charge the collector, *P*, or the wire, *W*, with your glass rod, until the leaves of the electroscope *begin* to diverge. Withdraw the condensing plate, the leaves fly asunder; bring the condensing plate near, the leaves again collapse.

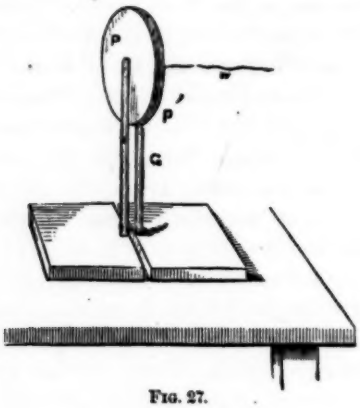

FIG. 27.

Or, vary your construction, and make your condenser thus: Employing the table, or a sheet of foolscap if the table be an insulator, as one plate of the condenser, spread upon it the sheet of India-rubber, *P*, Fig. 28, and lay upon the rubber the sheet of block-tin, *A*, *B*. Connect the tin by the wire, *W*, with the electroscope, *T R L*. Impart electricity to the little weight, *A*, till the leaves, *L*, begin to diverge; then lift the tin plate by its two silk loops; the leaves, *L*, at once fly asunder.

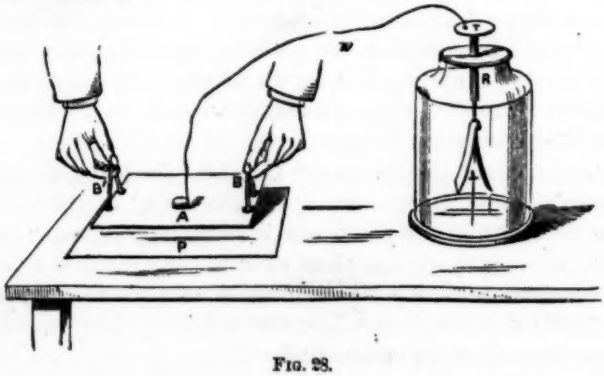

FIG. 28.

Finally, show your complete knowledge of the Leyden-jar, and your freedom from the routine of the instrument-makers, by making a "jar," in the following novel way: Stand upon a board supported

by warm tumblers. Hold in your right hand a sheet of vulcanized India-rubber, and clasp, with it between you, the left hand of a friend. Place your left hand on the conductor of the machine, and let it be worked. You and your friend soon feel a crackling and a tickling of the hands, due to the heightening attraction of the opposite electricities across the India-rubber. The hand-jar is then charged. To discharge it you have only to bring your other hands together: the shock of the Leyden-jar is felt.

By the discharge of the hand-jar you can fire gunpowder. But this will be referred to more particularly further on.

SEC. 20. *Physiological Effects of the Shock.*—The physiological effect of the shock was variously studied. Graham caused a number of persons to lay hold of the same metal plate, which was connected with the outer coating of a charged Leyden-jar, and also to lay hold of a rod by which the jar was discharged. The shock divided itself equally among them.

The Abbé Nollet formed a line of one hundred and eighty guardsmen, and sent the discharge through them all. He also killed sparrows and fishes by the shock. The analogy of these effects with those produced by thunder and lightning could not escape attention, nor fail to stimulate inquiry.

Indeed, as experimental knowledge increased, men's thoughts became more definite and exact as regards the relation of electrical effects to thunder and lightning. The Abbé Nollet thus quaintly expresses himself: "If any one should take upon him to prove, from a well-connected comparison of phenomena, that thunder is, in the hands of Nature, what electricity is in ours, and that the wonders which we now exhibit at our pleasure are little imitations of those great effects which frighten us, I avow that this idea, if it was well supported, would give me a great deal of pleasure." He then points out the analogies between both, and continues thus: "All those points of analogy, which I have been some time meditating, begin to make me believe that one might, by taking electricity as the model, form to one's self, in relation to thunder and lightning, more perfect and more probable ideas than what have been offered hitherto.[1]"

These views were prevalent at this time, and out of them grew the experimental proof by the great physical philosopher, Franklin, of the substantial identity of the lightning-flash and the electric spark.

Franklin was twice struck senseless by the shock. He afterward sent the discharge of two large jars through six robust men; they fell to the ground and got up again without knowing what had happened; they neither heard nor felt the discharge. Priestley, who made many valuable contributions to electricity, received the charge of two jars, but did not find it painful.

[1] Priestley's "History of Electricity," pp. 151, 152.

This experience agrees with mine. In the theatre of the Royal Institution, and in the presence of an audience, I once received the discharge of a battery of fifteen Leyden-jars. Unlike Franklin's six men, I did not fall, but, like them, I felt nothing. I was simply extinguished for a sensible interval.

This may be regarded as an experimental proof that people killed by lightning suffer no pain.

SEC. 21. *Seat of Charge in the Leyden-Jar.*—Franklin sought to determine how the charge was hidden in the Leyden-jar. He charged with electricity a bottle half-filled with water and coated on the outside with tin-foil; dipping the finger of one hand into the water, and touching the outside coating with the other, he received a shock. He was thus led to inquire, Is the electricity in the water? He poured the water into a second bottle, examined it, and found that it had carried no electricity along with it.

His conclusion was, that "the electric fire must either have been lost in the decanting or must have remained in the bottle. The latter he found to be true; for, filling the charged bottle with fresh water, he obtained the shock, and was, therefore, satisfied that the power of giving it resided in the glass itself."[1] An account of Franklin's discoveries was given by him in a series of letters addressed to Peter Collinson, Esq., F. R. S., from 1747 to 1754.

So much for history; but you are to verify the history by repeating Franklin's experiments. Place water in a wide glass vessel; place a second glass vessel within the first, and fill it to the same height with water. Connect the outer water by a wire with the earth, and the inner water by a wire with the electric machine. One or two turns furnish a sufficient charge. Removing the inner wire, and dipping one finger into the outside and the other into the inside water, a smart shock is felt. This was Franklin's first experiment.

Pass on to the second. Coat a glass jar with tin-foil (not too high); fill it to the same height with water, and place it on India-rubber cloth. Charge it by connecting the outside coating with the earth, and the water inside (by means of a stem cemented to the bottom of the jar and a knob) with an electric machine. You obtain a bright spark on discharging. This proves your apparatus to be in good order.

Recharge. Take hold of the charged jar with the India-rubber, and pour the water into a second similar jar. No sensible charge is imparted to the latter. Pour fresh unelectrified water into the first jar, and discharge it. The retention of the charge is shown by a brilliant spark. Be careful in these experiments, or you will fail, as I did at first. Note that the edge of the jar out of which the water is poured is to be surrounded by a band of bibulous paper to catch the final drop.

[1] Priestley's "History of Electricity," third edition, p. 149.

These experiments are now made by rendering the coatings of the Leyden-jar movable. Such a jar may be charged, the interior coating may be lifted out and proved unelectric. The glass may then be removed from the outer coating and the latter proved unelectric. Restoring the jar and coatings, on connecting the two latter, the discharge passes in a brilliant spark.

Make a jar with movable coatings thus: Roll cartridge-paper round a good flint-glass tumbler, *G*, Fig. 29, to within about an inch of the top. Paste down the edge of the paper, and put a paper bottom to it corresponding to the bottom of the glass. Coat the paper, *T*, inside and out with tin-foil. Make a similar coating, *T'*, for the inside of the tumbler, attaching to it an upright wire, *W*, ending in a hook. You have then, to all intents and purposes, a Leyden-jar.

Fig. 29.

Fig. 30.

Charge the jar, and by means of a rod of glass, sealing-wax, or gutta-percha, lift out the interior coating. It will carry a little electricity away with it. Place it upon a table and discharge it wholly. Lift the glass by the hand out of the outer coating. Neither of the coatings now shows the slightest symptom of electricity. Restore the tumbler to its outer coating, and, by means of the hook and insulating rod, restore the inner coating to its place. Discharge the jar: you obtain a brilliant spark. The electricity which produces this spark must have been resident in and on the glass.

You can charge your jar with a rubbed glass rod, though a machine in good working order will do it more rapidly.

Sec. 22. *Ignition by the Electric Spark.*—Various attempts had been vainly made by Nollet and others to ignite inflammable substances by the electric spark. This was first effected by Ludolf, at

the opening of the Academy of Sciences by Frederick the Great, at Berlin, on the 23d of January, 1744. With a spark from the sword of one of the court cavaliers present on the occasion, Ludolf ignited sulphuric ether.

Dr. Watson also made numerous experiments on the ignition of bodies by the electric spark. He fired gunpowder and discharged guns. Causing a spoon containing ether to be held by an electrified person, he ignited the ether by the finger of an unelectrified person. He also noticed that the spark varied in color when the substances between which it passed varied.

These, and numerous other experiments, may be made with a far simpler "machine" than any hitherto described. It was devised for your benefit by Mr. Cottrell. In the electric machine, as we have learned, the prime conductor is flooded with positive electricity through the discharge of the negative from the points against the excited glass. Your glass tube may be similarly turned to account. A strip of sheet-brass or copper, *P*, Fig. 30, about five inches long and one inch wide, is sewn on to the edge of the silk pad, *R*, employed as a rubber. Through apertures in the strip of metal about twenty pin-points are introduced and soldered to the metal. When the tube is clasped by the amalgam-covered rubber, the metal strip and points quite encircle the tube.

When a fine wire, *w*, connects the strip of metal with the knob of a Leyden-jar, by every downward stroke the glass tube is powerfully excited, and hotly following the exciting rubber is the circle of points. From these, against the rod, negative electricity is discharged, the free positive electricity escaping along the wire to the jar, which is rapidly charged.

Connecting the strip of metal with an insulated metallic knob, placed within a quarter or an eighth of an inch of an uninsulated argand burner, at every downward stroke of the rubber a stream of sparks passes between the knob and burner. If gas be turned on, it is immediately ignited by the stream of sparks. Blowing out the flame and repeating the experiment, a single stroke of the tube infallibly ignites the gas. Sulphuric ether, in a spoon which has been previously warmed, is thus ignited: but the ether soon cools by evaporation; its vapor is diminished, and it is then less easy to ignite. Bisulphide of carbon may be substituted for the ether, with the certainty that every stroke of the rubber will set it ablaze.[1] The spark thus obtained also fires an electric pistol charged with a mixture of oxygen and hydrogen. The two gases unite with explosion to form water, when an electric spark is passed through them.

Mr. Cottrell has mounted his glass tube so as to render friction in both directions available. The *tube-machine* is represented in Fig.

[1] I am indebted to Dr. Debus for the suggestion of the bisulphide as a substitute for the ether.

31. *A B* is the glass tube, clasped by the rubber, *R*. *P P'* are strips of metal furnished with rows of points. From *P P'* wires proceed to the knob *C*, which is insulated by the horizontal stem, *G*, from the stand of the machine. This insulating stem may be abolished with advantage, the wires from *P* and *P'* being rendered strong enough to support the ball *C*. At *C* sparks may be taken, a Leyden-jar charged, the electric mill turned, while wires carried from it may be employed in experiments on ignition.

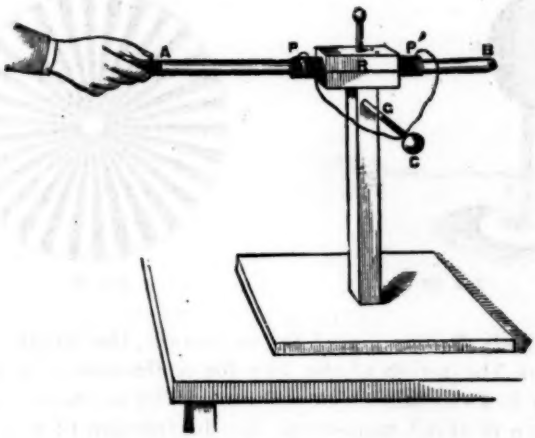

FIG. 31

"Seldom," says Riess, "has an experiment done so much to develop the science to which it belongs as this of the ignition of bodies by the electric spark." It aroused universal interest: the experiment was repeated in all royal houses. Money was ready for the further prosecution of electrical research. The experiment afterward spread among the people. Klingenstierna astonished King Frederick of Sweden by igniting a spoon of alcohol with a piece of ice. Riess considers it probable that the general interest thus excited led to the discovery of the Leyden-jar, which was made soon afterward.

Cadogan Morgan, in 1785, sought to produce the electric spark in the interior of solid bodies. He inserted two wires into wood, and caused the spark to pass between them: the wood was illuminated with blood-red light, or with yellow light, according as the depth at which the spark was produced was greater or less. The spark of the Leyden-jar produced within an ivory ball, an orange, an apple, or under the thumb, illuminates these bodies throughout. A lemon is especially suited to this experiment, flashing forth at every spark as a spheroid of brilliant golden light. The manner in which the lemon is mounted is shown in Fig. 32. The spark occurs at *s*. A row of eggs is also brilliantly illuminated throughout at the passage of every spark from a Leyden-jar.

SEC. 23. *Duration of the Electric Spark.*—The duration of the electric spark is very brief: in a special case, Sir Charles Wheatstone found it to be $\frac{1}{14000}$th of a second. This, however, was the maximum duration. In other cases it was less than the millionth of a second.

FIG. 32.

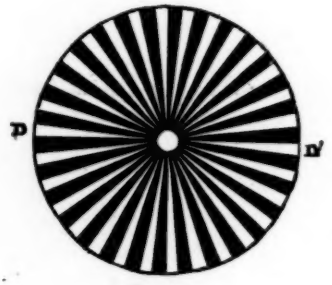

FIG. 33.

When a body is illuminated for an instant, the image of the body remains upon the retina of the eye for a fraction of a second. If, then, a body in swift motion be illuminated by an instantaneous flash, it will be seen to stand motionless for the fraction of a second at the point where the flash falls upon it. A rifle-bullet passing through the air, and illuminated by an electric flash, would be seen thus motionless; a circle like *D D'*, Fig. 33, divided into black and white sectors, and rotating so quickly as to cause the sectors to blend to a uniform gray, appears, when illuminated by the spark of a Leyden-jar, perfectly motionless, with all its sectors revealed. A falling jet of water, which appears continuous, is resolved by the electric flash into its constituent drops.

For a long time it was found almost impossible to ignite gunpowder by the electric spark, its duration was so brief; the powder, when the discharge occurred in its midst, was simply scattered violently about. In 1787 Wolff introduced into the circuit through which the discharge passed a glass tube wetted on the inside. He thereby rendered the ignition certain. This was owing to the retardation of the spark by the imperfect conductor. Gun-cotton, phosphorus, and amadou, which are torn asunder by the unretarded spark, are ignited when the discharge is retarded by a tube of water. A wetted string is the usual means resorted to for retardation when gunpowder is to be discharged.

The instrument usually employed for the ignition of powder is called a universal discharger. It is represented in Fig. 34. *I* and *I'* are insulating rods of glass or sealing-wax, supporting two metal arms, the ends of which can be brought down upon the little central

table. Surrounding their ends with powder at *S*, and sending through the powder the unretarded charge, the powder is scattered mechanically. Introducing the wet string *w* into the circuit, it infallibly ignites.

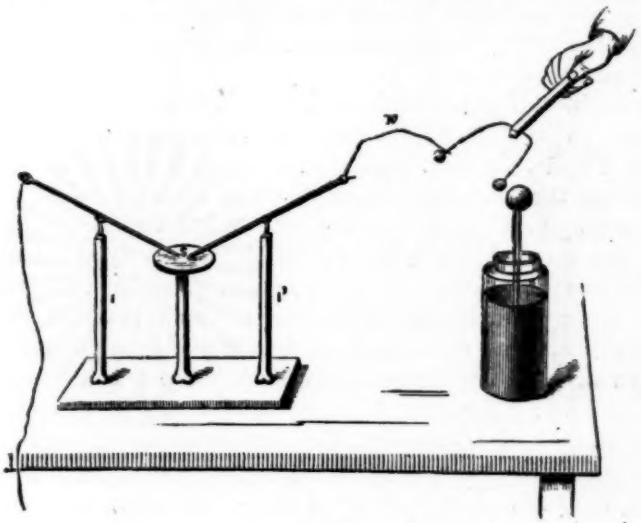

FIG. 34.

CERTAIN PHASES OF BIRD-LIFE.

BY CHARLES C. ABBOTT, M. D.

NOTWITHSTANDING so general an interest has been taken in studying the habits of our birds, by both scientific and amateur naturalists, there are several phases of bird-life to which little or no attention has been paid; at least scant reference, if any, has been made to them, in ornithological literature.

One such feature of bird-life is the mode of acquiring the range of flight-power characteristic of each species. A careful and long-continued study of our birds in their chosen haunts, free from all unnatural (i. e., human) persecution, has enabled me to detect but little variation in the flight-powers of the individuals of any species of bird observed —far less than in the general range of their habits; but still, such individual variation, I think, does exist. A bird is not a perfectly-adapted machine, capable of faultlessly filling its destined place in Nature, and unerringly performing everything required of it. With the simple growth of the feathers of the wing, there does not come the ability to fly. Just as creeping precedes walking, in children, this is a gradually-acquired power. The commencement may be termed

"flapping," and consists in simply breaking the force of a descent; this is followed by a more effectual use of the wings, and horizontal progression, and it is some time subsequent to this that the young birds attain to the power of *upward* flight. This holds good of a considerable number of species, studied with special reference to their flight, as the robin, the wood-thrush, cedar-bird, cat-bird, pewee, and indigo-bird.

It is doubtful if young birds, while yet in their nests, are conscious of the use to be made of their wings. After long-continued experimenting, I find they make no use of them, in endeavoring to escape, but trust to their legs entirely, if removed from the nest, or defend themselves by pecking at the intruder. When a sufficient growth of feather has been obtained, the parent-birds, directly and indirectly, instruct them; or, perhaps more properly, force them to use their wings. So, at least, I can only interpret certain habitual actions of the parent-birds with reference to their newly-fledged young.

As an instance I will quote from my field-notes, with reference to the indigo-bird: "June 23, 1873. Found a nest of this species in a dense thicket of blackberry, and, curiously enough, within just seven paces of the railroad-track. The young birds were just ready to leave the nest. I visited the nest the next day, and saw on my approach one of the four young birds sitting on a brier-stem, about a yard from the nest. Taking a favorable position, I continued to watch the birds closely, as they were very restless and noisy. Evidently something unusual had occurred or was occurring. In a few moments I saw the hen-bird go to the nest and push one of the young birds out of the nest. It forced it from the edge of the nest, to which it clung with its feet. Once free, the little fellow struggled to keep itself up, throwing *up* its wings, as a child would straighten out its arms when falling. This was the initial movement that developed into flight. All of the young birds were thus forced from the nest, and I am satisfied from no outside cause, as, for the three following evenings, the young returned to the nest to roost. I spent several hours watching this brood and their parents, and the whole time was occupied, except short intervals when they were fed, in forcing the young birds from point to point, but ever keeping them from the railroad-track, over which trains passed frequently. Two days from leaving the nest they could fly six or eight yards, but always from a higher to a lower perch, and regained the more elevated branches by very short, 'jumping' flights, with a laborious flapping of the wings; but on the fifth day they could follow their parents almost any distance, and execute an upward flight with apparently the same ease. Examination of the wing-feathers on the 30th of June, as compared with a week previous, showed so slight gain in the growth of the feathers, that I believe nothing in the increased flight-power was due to their being now better fledged."

Such observations as the one noted in detail I have so frequently repeated with widely-differing species as to satisfy me that what may be termed "direct instruction" in flight is given to the young birds by their parents. "Indirect instruction" also is noticeable, in the fact that the parent-birds cease to feed their young, and so force the latter to leave the nest and follow them. Once out of the nest, they soon endeavor to walk on air, as it were, and, falling, open their wings, and, as described, thus take the initial step. This ceasing to bring the food to the young while yet in the nest is done in some instances, I judge, only to draw them from the nest; and then they feed them as before, but not as frequently, which leads the young to voluntarily move from point to point. The important fact must not be lost sight of, too, that the young birds, when once out of the nest, witness nearly every movement of their parents, and learn, undoubtedly, very much through imitation of their movements.

For these reasons, I believe the acquisition of full flight-power is gradually acquired; first there is a mere "flapping" to prevent falling; then short horizontal stages of aërial progression; finally, a steady, intelligent use of the wings, enabling the birds to execute the highest type of flight within their capabilities, i. e., upward flight.

In the case of birds of more complicated flight than those mentioned above, such as the falcons, where hovering is a necessary acquirement, the truth of the assertion that flight is gradually acquired becomes more evident from the fact (which I have very frequently verified by observation) that the young birds for some time after leaving the nest are fed by their parents. They commence procuring food for themselves by chasing sparrows; checking their moderate flight when above a thicket, they rush upon the fleeing birds, more frequently without success than with. Their first attempts at hovering are miserable failures, and it is not until autumn that they are enabled, by the complete control of their wings, to stay themselves in mid-air, and, at the proper moment, dart with unerring aim upon some luckless mouse.

I have used the term "unerring," because it is customary so to characterize this act of the falcons; but, having watched, with a powerful field-glass, the hovering and darting of hawks, I have been forced to consider the term far from correct, and that not more than one-half, if as many, of the "strikes," on the part of the bird, are effectual.

Following the young birds, of any species, from the nests, and noting their movements, we find that the one prominent aim of their lives, during their first summer, is the acquisition of food. They have really nothing else to do, if we except escaping from the attacks of their enemies, and this is taught them directly by their parents. I judge that the great majority of birds that fall victims to birds of prey and carnivorous mammals are young. To return to the feeding-habits of birds. These appear to be acquired, by every bird, through

imitation of the movements of the parents when in search of food; judgment as to localities, on the part of the young, and allied circumstances connected with procuring food, come by experience. Watch a restless little creeper, during these chill winter mornings (*Certhia familiaris*), as it flies from tree to tree, and clambers over and about the rough bark. It seems, indeed, a mere automaton, driven, and not going of its own free-will; but, if we continue our observations but a little longer, we shall find it really a discriminating creature, passing by certain trees that are to us all one with those visited. It is not chance, but a consciousness of the uselessness of search, that determines its flight to some more distant rather than a nearer tree.

As an example of the knowledge gained by young birds through imitation, let us take young woodpeckers. On leaving the nest, they accompany their parents, but are not fed by them. Like the old birds, they immediately commence to climb the trunks and branches of the trees. Having been fed with insects when in the nest, they are already able to recognize their proper food, and devour the visible insects they may discover on the outer surface of the bark. Now, was it the example set by their parents, or the peculiar construction of their bill and feet, that was the cause of their having sought the trees, and climbed over them in the peculiar manner common to their kind? I think, clearly the former. Now, merely clambering over the bark of trees would not enable them to secure sufficient food, and imitation could not extend beyond this point; but here experience comes into play, and the gradual acquirement of the whole routine is easily traced. The bark of trees is nearly always cracked, and in the crevices are more insects than on the surface, and the habit, soon acquired, of search in the cracks of the bark is the one step from searching over the exposed surface to search beneath. Imitation led the *ignorant* young bird to the thrifty growth of timber, and not the tangled hedge-rows. Experience taught him the accustomed haunts of those insects on which Nature bids him prey. If we go back into the remote past, and recall the ancestral woodpecker, we can with no undue use of the imagination picture to ourselves the first steps that led the good climber to find in the half-decayed bark the nourishing food abounding there; and now let us return to the present, and seek for some variation in the habits of the birds of to-day. As an instance, the "flicker," or golden-winged woodpecker, leaves the timber-lands, and in loose flocks, often in company with robins, wanders over pasture-fields and meadows in search of food, more especially the crickets, and not under fences do they look for them, but under the dry droppings of the cattle. Here is an instance where accident, it may be, gave origin to, and experience has confirmed into a habit, a decided variation from normal woodpecker life. Now, a young woodpecker leaving its nest June 1st, if dissociated from its kind, would never leave the woodlands, and, seeking the

pasture-fields, overturn dry chips of cow-dung, in search of crickets; but such young birds will naturally follow their parents thither, and this is just the case, for the larger proportion of birds killed in October, in such localities, are the young of the preceding summer.

In conclusion, with reference to young birds, I believe they leave their nests *totally ignorant*, and *naturally* imitate their parents. What this imitation secures to them, in the way of knowledge, they perfect by experience; and this explains the variation in the habits of the same birds, so noticeable when studied in localities widely distant and greatly differing in character.

Let us turn our attention now to adult birds; and, with reference to them, I would refer particularly to two phases of their life-habits that have interested me exceedingly. The first of these points is the ingenuity so frequently displayed in procuring food. By the exercise of ingenuity, I mean instances of the attacking bird (in cases of birds of prey) being at first outwitted by the pursued, and, after repeated efforts availing nothing, ceasing its aggressive movements; then considering the causes of failure, planning a new method of action, and, having correctly judged the difficulties, finally succeeding. This, at least, is the manner in which I interpret the following instance:

While out watching our winter birds, January 22d of this year, I was caught in quite a hard shower, and sought shelter under a group of three large, dense cedars. Like myself, driven in from the adjoining meadows by the increasing rain, came a dozen or more sparrows, which, settling among the branches, commenced dressing their feathers and twittering cheerily. In a few moments after came, with a rush and loud chirp, a gay cardinal. If the sparrows did not acknowledge his presence with a low bow, each, at any rate, took a lower branch, leaving him on his elevated perch like a monarch on his throne. But he was fated to be molested, for, scarcely had he become fairly settled, and his feathers smoothed, when a sparrow-hawk rushed through the tree, with a zigzag movement, endeavoring to seize him or one of his attendant sparrows. Failing in this, the hawk hovered about a few moments, giving the scattered birds time to return, which they quickly did, when, with a similar rush, he again scattered them. One little snow-bird was so thoroughly frightened that it lit upon my shoulder, as though seeking safety under the brim of my hat. The third effort of the hawk failing, he came back immediately and seated himself at a little distance from the top of the tree, and close to the main stem. I remained nearly motionless, but with upturned face, and could plainly see the bird, although fortunately I escaped notice. One thing in particular attracted my notice: the bird was very much exhausted, "out of breath," as we should say of ourselves, and, with his beak open, he panted violently. This satisfied me that the efforts to capture prey are not accomplished with the ease sometimes supposed. As the rain was increasing, and the wind con-

siderable, the sparrows again collected in the tree; and now the hawk rushed *out* instead of in, and bore a luckless sparrow in his claws.

I think that we have here all that I claimed, when speaking of ingenuity on the part of adult birds in seeking their food. There was in the above instance a painful consciousness, at first, of failure to secure the desired prey; there was a determination to succeed, in spite of failure at the start, and a correct determination of the cause of failure, coupled with the invention of a plan by which the difficulties might be overcome. What more should be required to demonstrate that the mental powers of lower animals differ from those of man solely in degree?

Again, let us consider a case of ingenuity displayed by a bird in successfully avoiding an enemy. Here there is more cause to be surprised at the result, inasmuch as there was no cessation of the attack, to give the pursued bird time for considering how best to act under the circumstances; but, while fleeing for life, it matured a plan of escape that happily succeeded. This instance of ingenuity on the part of a pursued bird I have already related (*Land and Water*, March 2, 1872), but, considering it more remarkable than any other that has occurred to my knowledge, and having witnessed a repetition of it, two years later, I again relate it, in preference to other instances I have noted, bearing upon the same subject. The case is that of a "king-rail" (*Rallus elegans*), which my spaniel flushed in open ground, the grass not being tall enough to conceal it. The bird trusted wholly to running, and kept clear of the dog; frequently it "doubled," and seemed to enjoy the chase; but, evidently becoming somewhat fatigued, as shown by the nearer approach of the spaniel, it ceased doubling, but, running in a straight line some distance, it allowed the dog to get within a foot or more, when it jumped, with a single flap of its wings, a foot or more from the ground; then dropping down quickly behind the dog, it turned and ran in the opposite direction, gaining considerable ground before the impetuous spaniel could check its speed, turn about, and follow. Here, again, as we would express it, in describing any human experience, "the circumstances of the case were taken into consideration" by the pursued bird, and, without taking to flight, as would seem the more natural act, it surmounted the difficulties, and effected its escape. I can conceive of no other way of explaining this action of the rail-bird, than by admitting that a train of thought passed through the brain of the bird—that it thought, "If I can gain time, I am safe," just as any pursued person would think that, if he could reach some spot, be heard, etc., he would be safe. And, while yet running at great speed, the bird *thought* of an ingenious plan, by which it *did* gain time, and reached the reedy creek-bank in safety

It might be argued that a single act of a bird, at some one time, and under peculiar circumstances, does not constitute a habit—that it simply chanced to do so and so; but a second occurrence of the kind

would result differently. It must be remembered, however, that where a bird is noticed in its natural haunts, once, even if for more than an hour—which is an unusually long observation—there are weeks when this same bird is unseen, and therefore what its acts may be are absolutely unknown. For this reason, an ingenious act of a bird may be frequently repeated, and almost certainly is. Indeed, our ignorance of bird-life is so great, that what seem to us "curious instances," because but seldom witnessed, are frequently daily occurrences, and ordinary features of the bird's life. It can scarcely have escaped the notice of close observers of our winter birds, that their comparative abundance is only during clear, pleasant weather, when they will be as lively and restless as spring birds in early summer, and that during the winter certain localities, as the southern outlooks of wooded hillsides and such sheltered spots, are those where these hardy species "most do congregate." During a mild day, at some such spot, we can almost delude ourselves into thinking that spring is coming; but on the morrow a fierce wind rattles the bare branches above you, clouds of stinging dust, or driving snow, fill the chilled air, and not a bird is to be seen or heard, the cheery sights and sounds of yesterday having given place to a dreariness most drear. One question now arises, and we naturally ask, "What has become of the birds, so lately here?"

During the winter of 1874–'75 (the coldest except one—1835–'36—since 1780), I endeavored to determine to what extent these birds sought shelter, and the character of it, not only as a protection against severe storms, but as regular winter quarters, i. e., for roosting-places. I was led to do this from the fact that these winter residents, as the bluebird, the cardinal redbird, and the titmouse, do not roost in the trees, as in summer, and it seemed probable that, seeking warmer quarters in ordinary weather, they should seek shelter from severe storms, and not temporarily migrate to some point beyond the limits of the storm; not only this, but that some spot is selected early in the season as such roosting-place and refuge, and occupied as such throughout the season. So far as my observations extend, I was correct in my surmises.

I have, on my farm, a deep "gully," or ravine, thickly wooded, and with overhanging banks, extending a considerable portion of the entire length. This overhanging earth is held in place, partly by the character of the soil, and more by the roots of the trees growing near the margins of the gully. In this locality, under the overhanging earth, in some instances at a distance of three feet from the open ground, I found the snow-birds, song and chipping sparrows, occasionally a flock of cedar-birds, the arctic snow-bird, and horned larks, roosting; and, judging from the amount of excreta upon the ground, this had been the accustomed roosting-place for many weeks. A little before sundown, during January, I would find these birds, some or

all of them, congregating in the adjoining fields and in the trees of the gully, and quite suddenly they would all disappear. Searching every possible hiding-place, I finally found them as above described. If the following day proved very cold or stormy, many of them would remain in their snug retreat, the arctic visitors being the first to venture out. The birds just mentioned all build open nests, either in trees or upon the ground. On the other hand, the titmouse, nuthatch, brown tree-creeper, and bluebird, all of which build nests in hollow trees, or sheltered spots of that character, I found regularly roosted in the hollow trees, or in the outbuildings of the farm. The cardinal redbirds, however, which nest in trees and brier-patches, usually took refuge in dense cedars, to roost, but sought other shelter during severe storms. For instance, during the remarkable windstorm of February 9th, when the air was filled with dust, and the thermometer ranged from 3° to 4½° Fahr., no ordinary shelter could protect our resident birds. During the day not one was to be seen flying. I found the cardinal redbirds—a pair of them—had taken shelter in a large, hollow tree, and with them was quite a large number of titmice, a brown tree-creeper (*Certhia familiaris*), and several sparrows. I do not doubt but that the earth-shelter already described had proved inadequate, and that the birds usually roosting there had sought more sheltered spots. However, I did not have the courage to face the wind, and see for myself, if such was the case.

During the present winter I have found that some, at least, of our winter birds utilize the very excellent shelter afforded by the nests of our bank-swallows. February 20th, a bright, clear day, I passed by a high, steep cliff of compact sand and clay, much frequented by these swallows during summer. I noticed there chipping-sparrows and a bluebird sunning themselves, each at the opening of a nest. On driving them away I found that they circled about for a few moments, and returned. On passing the cliff again, some hours later, I saw these birds, and several others, some at the openings of the nests, and others flitting about, quite in the manner of swallows. I could not reach the nests, to determine if they had been much occupied during the winter, but do not doubt but that such was the case.

I have not found, however, any shelters constructed by birds for such purpose solely, except in the case of the introduced English sparrow, which builds quite an elaborate and very warm roosting-nest. During the early frosts of autumn and prevalence of cold rain-storms, occurring before the ordinary date of migratorial departure, the nests used in spring and summer are, I know, used as roosting-places, but I have not detected any refitting of them for this purpose. Considering this, it would be natural for birds to build new structures for winter use, and in the sparrow we have an instance of it, and, I presume, the abundance of natural shelter has alone prevented the gradual acquirement of this habit by our winter birds.

Having familiarized one's self with the various phases of bird-life, as it occurs in the open fields, dense thickets, along secluded streams, and in shady forests, one can scarcely conclude otherwise, if happily he has not entered upon his studies with some preconceived notion, than that these wild and wary falcons, timid sparrows, fiery little wrens, and cautious waterfowl, are creatures that, like man himself, are thrown upon the world dependent upon their own exertions, guided by their own reasoning powers. There are no prearranged rules which, when birds leave their nests, they must strictly follow, to exist. Given that knowledge which comes through direct and indirect instruction from the parent-birds, and a young bird, having the world before it, exercises just those mental powers that man exercises, but limited just so far as its own wants are less than man's wants as man. Finally, in the chance occurrence of some peculiar habit have we not a trace of the former mode of life of some far-distant ancestral form; and, in the undeniable irregularity of all habits, can we not discern unmistakable indications of the gradual adoption of every habit, just as the various specific forms themselves gradually emerged from the archaic creature that, appearing in the dim past, foreshadowed the gigantic condor of the Andes, and the petulant humming-birds of our summer gardens?

"OF THE UNCERTAINTY AND VANITY OF THE SCIENCES."

By IRWIN RUSSELL.

ABOUT three hundred and fifty years ago, Henry Cornelius Agrippa wrote a very curious book, "De Incertitudine et Vanitate Scientiarum" (Of the Uncertainty and Vanity of the Sciences). Few people read it now. Yet it has its interest, as an exponent of the state of science at that day, aside from the attractions which are given it by the quaint, sarcastic style of the author.

Here it is, a very old edition, in the black-letter of the sixteenth century. The text has numerous peculiarities. The letter "ā," with a dash over it, represents "an;" there are two kinds of "r's;" the double "e's" and double "o's," respectively, are put on a single type. The emphasized words are printed in Roman characters, whereof the font contains no "w," and that letter is made by placing two "v's" together. The book is numbered by folios, instead of pages. The printer tells us that his edition is translated from the original Latin, compared with an Italian version. Let us transcribe some of Agrippa's remarks—altering the spelling to suit our modern rules.

Above all sciences, he favors geometry: "In fine, all the cunning that is in Painting, in the Measuring the world, in ground tilth and trimming, in the Art of war, in founding of metals, in the art of working Images in earth, in Image-making, in forging, in building and in metals, for the most part, cometh from geometry." He says, however, of the geometricians: "Yet such is their ambition, that they will never rest upon the precepts of their preceptors; but believing in such things to find out more than their Masters, do bring themselves into so great madness that all the Helleborus in the world sufficeth not to purge it." He instances as the fruits of this science, "all the cunning working of tools and artificial instruments, *Magnaries*, *Machanopocetickes*, *Poliorcetickes*, ... *Testudines*, *Cuniculines*, ... *Exosters*, *Sambukes*." Between paragraphs, the reader can consult the dictionary or encyclopædia.

We are told in cap. 23, "Of the Arte Opticke," that "there are sundry and divers opinions of the manner of seeing. For Plato supposeth the sight to be made according to the clearness: to wit, that which cometh from the eyes: the Light running to an outward air, that Light which is carried from the bodies being brought against it; but that which is about the midst of the air, doth cause that it spreadeth, and turneth back to the virtue of the Sight, being spread abroad, and like unto Fire. Galene and Plato are of one opinion; but Hipparchus saith, that the beams spreading abroad from the eyes unto bodies, touching them as it were with a certain feeling, or groping, do give that which they receive to the Sight. And the Epicures affirm that the similitudes of things not corporal, but according to the quality through the alteration of the air, which is in compass, doth come from visible things unto the sight. But Porphirius saith that, neither the Beams, neither the similitudes, nor any other thing, is the cause of seeing, but the soul alone, that knoweth herself visible, and that is one of all things, which knoweth herself in all things that are. The geometricians and perspectivians, approaching somewhat near to Hipparchus, do affirm that there be certain Figures made of the meeting together of the beams, which are sent out through the eyes, from whence the sight doth comprehend in one, many visible things, but they most certain of all, wheresoever the beams shall meet together. Certes, Alchindus saith otherwise of the Sights: but it seemeth to Augustine that the power of the Soul doth bring somewhat to effect in the eyes, the which is not yet perceived of the Students of Wisdom."

Although we have advanced much since the time of Cornelius Agrippa, still, even in this glorious nineteenth century there is here and there a thing "the whiche is not yet perceyved of the Studentes of Wisedome."

The following is a good example of our author's peculiar style: "Notwithstanding, I learned in time past in Italy, that there was in pictures and images an authority greatly to be esteemed; for whereas

there was an obstinate strife between the Augustine Friars and the vulgar Canons, before the pope, concerning the habit or apparel of S. Augustine, that is to say, whether he did wear a black weed upon a white Coat, or a white weed upon a black Coat; and finding nothing in the Scriptures which made to the ending of this strife, the Roman judges thought good to prefer the whole matter to Painters and Image-makers, and that which they could avouch out of ancient Pictures and Images should be holden for a Definitive sentence. I being grounded upon this example, when some time I with exceeding great diligence searched for the Original of the Friars' cowl, and could find nothing for that matter in the Scriptures, at length I went me to the Painters, and for this thing I sought in the Cloisters, and in the cells of the Friars, where for the most part the histories of both Testaments are painted; and when I could not find in all the Old Testament none of the Patriarchs, none of the Priests, none of the Prophets, none of the Levites, nor yet Helias himself, whom the Carmelitans would have to be their Patron, with a cowl: taking the New Testament in hand, I found there Zacharie, Symeon, John Baptist, Joseph, Christe, the Apostles, the Disciples, the Scribes, the Pharisees, the High Priest Annas, Caiphes, Herode, Pilate, and many other, I saw in no place a Friar's cowl: and again diligently examining everything from the beginning, immediately in the fore part of the History the Devil was painted with a Cowl, to wit, he which went to tempt Christ in the Desert. I rejoiced exceedingly that I had found that in the pictures which until that time I could not see in writing, that is to say, that the Devil was the first author of a cowl: of whom afterwards, I suppose, that other Monks and Friars took up the fashion under divers colors; or, perhaps, have retained it as a thing left to them by inheritance."

Such passages as the last, which abound in the book, were not calculated to win for the writer the affection of the clergy. Through their influence, Agrippa was imprisoned for some time, and his pension from the Emperor of Austria was withdrawn.

"Seeing glasses" he classifies as follows: "The hollow, the embossed, the plain, the *Columnarie*, the *Piromidal*, the *Turbinal*, the bunched, the round, the cornered, the inversed, the eversed, the regular, the unregular, the massy, and the clear." He describes their properties, and says: "And I know how to make Glasses, in which, when the sun shineth, all things that are lightened of his beams may very plainly be seen a great space off, as three or four miles." Were these "glasses" on the principle of the telescope? The invention of that instrument is generally assigned to Galileo, about 1590; whereas Agrippa's book was published at Antwerp in 1530.

Astronomy he pronounces "altogether false, and fuller of trifling toys than the fables of the Poets"—declaring that the laws of the science, as then asserted, were only a mass of idle conjectures.

Of magic he says: "The things which the deluded and bewitched persons do imagine, have no truth of action and being, save only things imagined. For the end of this skill is not to do, simply, but to stretch out Imaginations even unto appearance."

The chapter on alchemy is a curiosity. One passage reads: "Finally, of that only blessed thing alone, besides which there is no other thing, yet to be found in every place, the subject of the most holy stone of the Philosophers, I mean, that is to say, I have almost rashly uttered the name of the thing, whereby I should be a sacrilege and forsworn, yet I will speak it with circumlocution, but somewhat more obscure, that none but young beginners in the Art and they which be trained up in the mysteries thereof may understand it. It is a thing, which hath substance, and not overmuch fiery, nor altogether earthly, nor simply watery, nor a most sharp nor most blunt quality, but indifferent, and light in touching, and after a sort tender, or at the least not hard, not unpleasant, but after a sort sweet in taste, sweet in smell, delectable to the sight, pleasant and jocund to the hearing, large to the imagination: I may say no more, and yet there be things greater than these." The description is scarcely definite enough to enable us to find the philosopher's stone.

The 102d chapter is "A Digression in prayse of the Asse"—after which follows the conclusion of the work, in which he salutes his readers, "O ye asses." Perhaps some modern authors would like to follow his example in this respect.

The printer, in his preface to this edition, remarks: "Sapience proceedeth of perfect Reason, joyned vvith Learning, and knovvledge, which if it be true, then consequently it followveth, that Artes and Sciences are good. And although this Authour sharply inveyeth against them, (vvhich to the rude multitude for that cause may seeme naught and noysome) yet his intent is not to deface the vvorthiness of Artes and Sciences, but to reprove and detect their euill vses, and declare the excellencie of his vvit in disprouing them, for a shevve of learning."

Henry Cornelius Agrippa was one of the most learned men of his time, and wrote voluminously upon scientific and philosophical subjects. The "Edinburgh Encyclopædia" says of him: "As a soldier and a physician, a lawyer and a lecturer, a metaphysician and a theologian, the versatility of his genius enabled him to attain the highest distinction." He wrote a "Dissertation on Original Sin," a work on "Occult Philosophy," a "History of the Government of Charles V.," and various other treatises. The book from which we have quoted so largely is undoubtedly the most complete summary of the condition of science at that day to be found in any one volume.

Is it probable that our present accepted theories will seem as curious to the reader of three hundred and fifty years hence as those of Agrippa's day appear to us? Will the customs, the manners, and the

laws of the world improve as rapidly in the future as they have in the past? If so, who would not wish to fall into such a trance as that of the Seven Sleepers—and wake, to find the rest of life all too short to enjoy the stupendous novelty?

ANIMAL POWERS OF OFFENSE AND DEFENSE.

THERE can hardly be any greater diversity observed in the animal series than that exemplified in the various means whereby animals are enabled to assume an offensive or defensive aspect. From the lowest to the highest grades of animal life—excepting, perhaps, man himself—we find ample provision made for the exigencies of animal existence, in so far as these exigencies demand the use of apparatus which gives its possessors some advantage or other in the "struggle for existence." Undoubtedly, in his superior intellectual organization, which enables man even in his rudest state to avail himself of almost every feature in his surroundings for advantage and defense, the human subject has been endowed above all other forms; and he therefore compensates himself by varied arts and stratagems for the want of the more rigid and natural appliances of lower forms. But if it be true that art is most to be admired when it closely imitates Nature, then the policy of man in his imitation, conscious or unconscious, of the many offensive arts of his humbler neighbors, must claim from us a fair share of favorable criticism.

Thus, it is a striking fact that very many human means of defense or offense find their prototypes, or at least strangely analogous features, in the extensive armory of the animal world at large. The lasso may be found in the apparatus whereby such a simple form as the *Hydra*, that tiny fresh-water polyp, secures its prey. Or, when human sharp-shooters think to conceal their whereabouts most effectually from the foes they purpose to annoy, and clothe themselves in garments of neutral tint, the hue of which shall most nearly resemble that of the objects amid which they are located, this principle of imitation of natural objects again finds a strict parallelism in the animal world. For it is a familiar fact to all observers of Nature that the color of most animals resembles more or less that of their natural surroundings. The color of the sand-grouse, for instance, and other species of grouse, of partridges and other birds inhabiting heaths, or of flounders and other fishes inhabiting the sand, strictly approximates in character to that of their dwelling-places, and serves to conceal and protect such beings. And, when we further discover that, in not a few cases, this principle of similarity to their surroundings is carried in

some animals—such as the leaf-insects and walking-stick insects—to the extent of close and actual *mimicry*, our surprise is increased.

Or, lastly, when we find, as in the latest phase of modern warfare, that the concealed torpedo is used as a subtile and powerful means for effecting the destruction of whole fleets, the fact cannot but call to mind the electrical apparatus of some fishes—and notably that of the torpedo or electric ray—which exists as a natural means of defense, the powers of which, few, if any, of their less favored neighbors care to test or provoke.

While the consideration of the more prominent and typical means of defense in animals may very reasonably occupy our brief attention, a few words on the subject of mimicry in the animal series may also prove interesting, more especially as this form of protection, through imitation of their surroundings, forms a simple yet effective means of defense to many organisms. We have already referred to the readily-perceived and very general correspondence in color seen throughout the animal world between animals and their abodes; and of the more general aspects of this condition nothing further need be said. The more special and striking developments of mimetic resemblances are found in cases in which not merely the general color of their environments is imitated, but where resemblances of a close, and sometimes of a very extraordinary kind, to other animals, to plants, or even to inorganic objects, are to be noted. In the leaf-insects, which are included in the same order as locusts, crickets, etc., for example, the wings are not only colored to resemble leaves, but their structure imitates in the most exact manner the appearance of the veins of the leaf. Nor does the principle of imitation end with this sufficiently remarkable effect. In some leaf-insects the colors of the leaf-like wings actually change with the season of the year; as if in the most perfect sympathy and harmony with the alteration of colors in the actual leaves. And the mimicry becomes of still more perfect kind, to our thinking, when we find that the wings of the leaf-insect exhibit even the characteristic markings we are familiar with in leaves as produced by the attacks of minute insects; Nature thus imitating, not merely the natural structure of the leaf, but the very imperfections to which the leaf is subject. It has been suggested that the little leaf-eating insects may be themselves deceived by the mimicry of their larger neighbors, and may actually eat into the wings of the latter, and thus produce the eroded appearance. But, if this latter view be correct, it only makes out a stronger case for the perfect reproduction of the leaves in the wings of the insect. Mr. Wallace has given us a very typical example of another such case of the imitation, not only of leaves, but of the natural parasites of leaves, in a butterfly, the wings of which, on their under-surfaces, resemble leaves; while the imitations of decay of leaves and of the fungi that appear thereon are so close that, as Mr. Wallace remarks, "it is impossible to avoid

thinking at first sight that the butterflies themselves have been attacked by real fungi."

The walking-stick insects, as they are called, in their turn imitate, in the skeleton-like structure of their bodies, the appearance of dried twigs; and it is a singular fact that even in their awkward, ungainly manner of walking, the resemblance to the chance movements of twigs is clearly perceptible; the mimicry being rendered more realistic through this latter phase. Then, also, we find certain harmless groups of moths imitating closely the outward appearance of species of stinging bees and hornets. And one remarkable case of mimicry is the well-known instance of some perfectly inodorous South American butterflies, which perfectly reproduce the external appearance of other butterflies which emit a most offensive odor; the reason assigned for this latter phase of mimicry being the very feasible one that the inodorous forms are protected from the attacks of birds by their resemblance to their strong-smelling neighbors. As a last instance of this curious phase of animal organization, we may note the example furnished by those curious little fishes, the *Hippocampi*, or sea-horses—so named from the obvious resemblance of the form of the head to that of a horse—the bodies of which become covered with long streamers of certain kinds of seaweed; so that, when these fishes rest amid the seaweed-covered nooks of their marine grottoes, the presence of their streamers serves to render detection by their enemies no easy matter.

Referring to the explanation, if such can be afforded, of these mimetic resemblances, there can be little doubt that, viewed as to its ultimate use and purpose, the condition of mimicry serves in the most effective manner as a means of defense and protection to the animals so endowed. The resemblance of the colors of birds to that of their habitat presents an obvious instance of this purpose; as also does the more complicated example of the imitation, by scentless butterflies, of their odorous neighbors. But, as regards the exact means whereby the condition of mimicry is induced and perfected, or concerning the exact causes of its assumption and development, natural history science, in its practical aspect, remains silent; although the bolder march of theory and speculation may indeed lead us for a little way toward the solution of the problem. At any rate, there can be no difficulty to our clearly appreciating the workings of a great law of purpose and design in the production of mimicry, as serving to protect the weak and less powerful against stronger and better-provided animals.

Turning now to some lower forms of animal life, we find in such forms as the *Hydræ*, or common fresh-water polyps, the zoöphytes, sea-anemones, jelly-fishes, and allied forms, excellent examples of very specific means of defense and offense in animals. Within the tissues of the bodies of the foregoing organisms, when these tissues are microscopically examined, numerous little sacs or cells, varying in size

and form, may be observed. To these cells the appropriate name of "thread-cells," or *cnidæ*, has been given. When their structure is investigated, each little cell is seen to possess an elastic wall of double nature; the inner layer of the wall being strong, while the outer one is of thinner and more delicate texture. The upper or open extremity of the inner layer of the sac is prolonged to form a kind of sheath, which protects and gives origin to a thread-like filament, from the presence of which, indeed, these cells derive their name. This thread, in the ordinary condition of the cell, is coiled up within the interior of the sac, and around its own sheath; and in many cases both thread and sheath may be discerned to be provided with minute spines or hooks. The cell itself, in addition, contains a fluid, amid which the thread is submerged.

Such is the essential structure of a thread-cell in its normal state of what we may term repose. When such a structure, however, is pressed or irritated in any way, the cell ruptures or bursts, the contained fluid escapes, and the thread and its sheath are quickly protruded or thrown out from the opening in the cell. If, now, the thread and fluid are observed to come in contact with any body of appropriate and assailable kind, such a body will exhibit certain symptoms which will indicate to us the probable nature of these curious cells. Thus, when the tentacles or feelers of the sea-anemone, or of any of the zoöphytes, come in contact with a minute or susceptible organism adapted for food, the organism is first observed to struggle to escape from the entwining filaments which encircle its body. Soon, however, its active exertions cease, and the victim appears paralyzed and incapable of helping itself, or of struggling longer with its captor. The thread-cells, in other words, have been discharging their miniature darts or "threads" into the body attacked; the fluid—in all probability of acrid or poisonous nature—has been poisoning the tissues of the struggling organism; and the observation has revealed to us that the functions of the cells are undoubtedly analogous to those of the serpent's fangs and poison-gland, in that they serve to paralyze and kill the prey.

As might naturally be supposed, the power of the thread-cells varies in different species and groups of the animals that possess them; but there are some forms of *Cœlenterata*—for thus the *Hydræ*, sea-anemones, and their allies, are collectively named—in which the stinging-cells are of sufficient size and power to inflict severe pain on man himself. Aristotle was fully aware of this latter fact when he named the jelly-fishes and their allies *Acalephæ*, or "nettle-like" animals. And bathers and swimmers, through instinct, if not thorough zoölogical knowledge, generally and wisely contrive to give the jelly-fishes a wide berth in their marine meanderings. The late Edward Forbes, in his humorsome manner, says of one species of jelly-fish, that, "once tangled in its trailing 'hair,' the unfortunate, who

has recklessly ventured across the graceful monster's path, too soon writhes in prickly torture. Every struggle," he continues, "but binds the poisonous threads more firmly round his body, and then there is no escape;" for, as the naturalist informs us, even when the arms or tentacles are cast loose from the body of the jelly-fish, they "sting as fiercely as if their original proprietor itself gave the word of attack." The Abbé Dicquemare, an observant French naturalist, found that some species can only sting the more sensitive parts of the body, such as the eyes. But Forbes's remark of the abbé's experiment, that most people would prefer "keeping their eyes intact, to poking medusæ into them," will coincide, we imagine, with the opinions of most of our readers. It is equally worthy of remark that "appearances" in natural history, as in ordinary life, are apt to be "deceptive;" and, looking at the grace and beauty of the jelly-fishes, we could hardly credit them with such virulent powers.

The most notable offenders of the jelly-fish class, in respect of their stinging powers, are the *Physaliæ*, or Portuguese-men-of-war, as they are popularly termed—a group of beautiful oceanic forms, met with floating far out at sea, especially in tropical latitudes, and presenting the appearance of a bladder-like structure, provided with a crest and trailing streamers, and colored of the most ethereal and beautiful of hues. When the tentacles of a physalia are allowed to come in contact with the human skin, the thread-cells—which are of large relative size, and measure in diameter about the three-thousandth of an inch—sting so severely that the effects of the irritation may persist for a considerable time, and may give rise in some cases to very painful after-effects. The thread-cells in the tentacles of the common species of sea-anemones have no effect on the skin of man; but, as the writer has frequently demonstrated on his own person, if the tentacle be allowed to touch the more delicate mucous membrane of the lips, a slight stinging sensation, accompanied by temporary numbness, may be felt. To the curious this is worth trying.

Passing in review the higher groups of the animal kingdom, we find an endless variety of contrivances subserving offensive purposes, or limited to the milder purposes of defense. Shells, scales, and plates of every kind, with special modifications for special purposes, may thus readily be selected as examples; spines and allied armaments of all shapes and sizes; poison-secretions and fangs of centipedes and serpents, and the sting of scorpions and bees, possessing sure and sometimes deadly effect on those they attack; and, in quadrupeds, strong claws and teeth united to equally powerful muscles—such are a few examples of the endless stores of weapons contained in animal armories.—*Chambers's Journal.*

SKETCH OF ALEXANDER BAIN.

PROFESSOR BAIN, of the University of Aberdeen, is a representative man of the modern school of English thought, who has done his best work in the field of psychology. His elaborate treatises upon the human mind now take a leading place in our literature, and are used as text-books in many colleges and universities. Besides this more special line of inquiry, to which Prof. Bain has given prominent attention, he has also been very active in the general field of higher education as lecturer, examiner, and author. He was born at Aberdeen, in 1818, and entered Marischal College, in the university of that town, in 1836, where he took the degree of M. A. in 1840. From 1841 to 1844 he taught as deputy the class of Moral Philosophy in Marischal College, and 1844–'45 he had charge of the class of Natural Philosophy in that institution. In 1845 he was elected Professor of Natural Philosophy in the Andersonian University at Glasgow. In 1847 he was appointed by the "Metropolitan Sanitary Commission" their assistant secretary, and in 1848 he was transferred to the same office in the General Board of Health, a post which he resigned in 1850. From 1857 to 1862 he held the position of Examiner in Logic and Moral Philosophy in the University of London. During several years from 1858 to 1870 he held the office of Examiner in Moral Science in the India Civil Service Department, and in 1860 he was appointed by the crown Professor of Logic in the University of Aberdeen. In 1864 he was reëlected examiner in the University of London, and continued to hold that position till 1869. Prof. Bain's first literary production is said to have been an article in the *Westminster Review*, published in 1840, and he subsequently contributed much to the pages of that periodical. In 1847–'48 he wrote text-books on astronomy, electricity, and meteorology, in Messrs. Chambers's school series, also several of Chambers's "Papers for the People," and the articles on "Language," "Logic," "The Human Mind," and "Rhetoric," in the "Information for the People." In 1852 he published an edition of the "Moral Philosophy of Paley," with dissertations and notes. "The Senses and the Intellect," his first independent and systematic work, appeared in 1855, and in 1859 was followed by "The Emotions and the Will," thus completing a new methodical exposition of the human mind. In 1861 appeared from his pen "The Study of Character," including an examination of phrenology. In 1863 he published an English Grammar, and in 1866 a "Manual of English Composition and Rhetoric." His more recent works are: "Mental and Moral Science," 1868; "Logic, Deductive and Inductive," 1870; and "Mind and Body," contributed to the "International Scientific Series," in 1873. In 1874 appeared "A Companion to the Higher English Grammar," "Exam-

ples and Discussions of Important Principles and Usages," intended as a help to the thorough mastery of English. Prof. Bain contributed the articles on "Logic" and "Mental Philosophy" to "Chambers's Encyclopædia," and contributed editorial notes to the recent edition of the works of James Mill. Prof. Bain was for many years the intimate friend and confidant of George Grote the historian, and was made by him heir in reversion (after Mrs. Grote's death) of all his copyrights. In connection with Prof. Croome Robertson, he edited Mr. Grote's posthumous work on "Aristotle," and he also edited Grote's "Minor Works," and prefixed to the edition an elaborate estimate of the character and writings of the historian. In connection with Dr. Taylor he is now engaged in a thorough revision of Arnott's "Physics," bringing it up to date, so that a new edition of this valuable and favorite work may be soon expected. He received the degree of LL. D. in the University of Edinburgh in 1869.

As a philosophic thinker, the influence of Prof. Bain is now very widely felt. He has made a powerful impression upon the mental science of the age by accepting the results of modern physiology and treating methodically of thought and emotion in connection with their physical concomitants. Though not disregarding the value of introspection, or the study of psychical phenomena in the changes of consciousness, he couples with this method the vigorous study of mental effects on their physical side, considering that there can be no mental science worth the name that does not carry its analysis down to the material conditions under which mind is manifested. The recognition of the corporeal nature as so fundamental a factor in mental science naturally drew his attention to the theory of organic development by which the higher organisms are explained on the principle of their derivation from the lower. This theory carries with it the necessary implication that the psychical nature of man, his intellectual faculties, emotions, and sentiments, are also derivative from lower conditions, and are only to be explained through the principle of descent. In the last edition of "The Emotions and the Will" this view is consequently adopted.

We give the readers of the MONTHLY an excellent likeness of Prof. Bain, probably the first that has appeared in this country. He is a man of slight stature, but of an active nervous temperament, a free and admirable talker, full of wit and anecdote, and a lively story-teller. He is broad and liberal in his opinions, and holds advanced views on the subject of education and university reform.

CORRESPONDENCE.

THE WATER-HAMMER.

To the Editor of the Popular Science Monthly.

SIR: The following phenomenon can, perhaps, be explained by yourself or one of your readers: I have a water-hammer, made of a straight tube of glass, about eighteen inches long and three-quarters of an inch in diameter. At the top of the tube there are two bulbs, the upper one about half the size of the lower, with only a narrow passage of about a sixteenth of an inch in width to connect the lower bulb with the tube, and the upper bulb with the lower. About one-third of the tube contains water. When the tube is inverted, and the water allowed to fill both bulbs, it will not, upon the tube being reversed, run out, but will remain in the bulbs for an indefinite time, until shaken or otherwise disturbed. This may be owing to adhesion simply, or, possibly, to capillary attraction, but it is not to this fact chiefly that I wish to call your attention. The water being in the bulbs, and the tube held with the bulbs upward, if a smart blow with the palm of the had be applied at the bottom of the tube, there arises, under certain conditions which I have been unable to determine, a ringing noise resembling sometimes the singing of a bird, sometimes the noise produced by a thin iron instrument—a fork, for instance—when knocked rapidly against an empty tumbler. During this time, no water escapes from the bulbs, but the water at the mouth of the lower bulb is violently agitated, as if small particles of air were quickly ascending to the height of a quarter of an inch in the bulb. Not a drop of water is displaced, the water remaining at the bottom of the tube not being perceptibly increased while the noise continues. It lasts sometimes from five to ten minutes, and it seems as though, under favorable conditions, it might continue indefinitely. Very frequently, however, the experiment does not succeed, though apparently all the conditions are exactly the same. Here, therefore, are two questions:

1. What is the reason why the water, when caused to enter the bulbs, does not flow out of them when the position of the tube is reversed, but remains stationary as if there was no such thing as gravity, and, in this case, a vacuum besides?

2. What is the reason of the singing noise above described? G. M.

NEW YORK, *March* 28, 1876.

To the Editor of the Popular Science Monthly.

WILL you allow me to state the precise ground of objection to your criticism of my book, "The Sexes throughout Nature?". "What she proposes to do," you affirm, "is nothing less than to reduce the whole organic world, with all its vital and physical characters, into exact and demonstrable quantitative expression."

I only insist that, until science can offer us exact quantitative proof that the total of male characters is in excess of the total of female characters, no scientist should assume to determine, on scientific authority, that woman is inferior to man. I make no attempt to place my hypothesis, that, *in each species of being, the sexes are true equivalents*, on a "demonstrable quantitative" basis.

Though presented in the form of equations, and defended in a series of carefully-argued propositions, the theory waits to be tested experimentally and quantitatively. It assumes to be nothing but a provisional hypothesis, destined to be either confirmed or rejected, as it is found to agree or not to agree with the decisive facts of Nature. I merely offer various evidence in defense of the assumption that, physical powers compared with physical, and psychical powers with psychical, the female is everywhere the equal of the male of its own species.

Unlike but mutually-adapted physical growth and expenditure, including the functions of reproduction, are held to balance and equalize the physical well-being of the sexes. It is further claimed that their psychical powers, dependent upon and working through adapted organisms, are also thereby maintained in a perpetually-adjusted equilibrium. The hypothesis assumes true mental equivalence, which is secured through inherent, varying, constitutional provisions.

My sole claim to originality must lie in the attempt to briefly and insufficiently indicate *how* Nature has wrought to achieve a continuous and progressive balance of the sexes from the beginning until now. It remains to complete the work; to determine *how much* of one set of characters is the mathematical equivalent of counterbalancing quantities.

Extremely accurate and detailed estimates are doubtless out of the question. The simplest computations are so inexact that even the mean distance of the earth from the sun still awaits revision. However, "in time," science must be able to offer sufficiently accurate, incontrovertible proof that men and women are, or are not, intellectually peers.

A. B. Blackwell.

Somerville, N. J., *March*, 1876.

THE "NEW PHILOSOPHY" OF HEAT.

To the Editor of The Popular Science Monthly.

In opening a copy of Bailey's Dictionary, published in London in 1775, my eye fell upon the following: "Heat (according to the *New Philosophy*) very much consists in the rapidity of motion in the smaller parts of bodies, and that every way; or in the parts being rapidly agitated all ways. Its operation upon the senses we call *Heat*, and is estimated according to its relation to the organs of feeling, which motion of its small parts must be brisk enough to increase or surpass that of the parts of the sentient, for if it be more weak or languid, it is said to be cold."

I was under the impression that the theory concerning heat which involves this definition is of modern development. What is the truth on the subject?

E. R. Craven.

The doctrine which makes heat consist in molecular motion, or in an agitation of the minuter parts of which material things are constituted, is old as a *speculation*, but modern as a scientific demonstration. Locke said, more than a hundred years ago, "Heat is a very brisk agitation of the insensible parts of an object, which produces in us that sensation from which we denominate the object hot, so that what in our sensations is *heat*, in the object is nothing but *motion*." Similar views may be vaguely traced in the writings of Galileo, Bacon, Newton, Leibnitz, Descartes, Bernoulli, and Laplace. But they were unverified conjectures, and could not take their place among the principles of science until experimentally proved. This was first done by Count Rumford, in his celebrated experiments at the Munich Arsenal, and published in the "Proceedings of the Royal Society for 1798." But Rumford's results were ignored for half a century. Dr. Whewell published the history of thermotics in 1837, without mentioning him. He was far in advance of his age, both in his philosophical views regarding heat and the experimental evidence by which he sustained them. When, from 1840 to 1850, various physicists and chemists entered upon lines of research that led to the general doctrine of the convertibility or correlation of forces, the labors of Rumford began to be appreciated, and the truth concerning the nature of heat being proved in various ways, became accepted in science and part of a "new philosophy," in a sense quite different from that in which these terms were used in the last century.

EDITOR'S TABLE.

THE RADIOMETER.

WE some months ago printed a paper describing briefly the leading features of Mr. Crookes's discovery of the mechanical action of light. We this month publish a more elaborate article under the same title, with new illustrations, in which the distinguished discoverer goes more fully into the subject, states how he was led into the investigation, explains the construction of the instrument, traces out the action of different kinds of rays, shows the value of the contrivance as a photometer or light-measurer, explains its magnetic and electrical relations and how its motions may be recorded, suggests its meteorological uses, and finally considers its results as determining the amount of the force of sunlight upon the earth. Nothing could better illustrate the wide and complex interactions and dependencies of natural phenomena than the circle of questions that is opened by the introduction of this ingenious invention.

The radiometer (so called because of its capacity of measuring radiations) is a very simple instrument (as will be seen by referring to Fig. 8, page 269), consisting of a small glass globe from which the air has been pumped out, and containing four arms supported at the centre by a fine point, and carrying at their extremities thin vanes or disks, white upon one surface and dark upon the other. When light from any source falls upon it the arms begin to revolve, the white surfaces approaching the light and the dark surfaces receding from it as if repelled or pushed away. We have before us a radiometer made by Geissler, the inventor of "Geissler's Tubes," which consists of a globe two and three-quarters inches in diameter, with its downward stem resting on a wooden base, the whole being ten inches high. It is in motion constantly in the daytime, propelled by the diffused light from the window, and, if the curtain be dropped and the room darkened, the faint light that comes in at the side maintains it in slow revolution. As the intensity of the light increases the motion is quickened, and when the instrument is placed directly in the solar rays the revolutions are so rapid that they cannot be counted. Mr. Crookes made one instrument so delicate that a single candle would drive it at forty revolutions per second.

In the hands of many the radiometer is now only a curiosity and a toy, yet to the physicist it is an instrument of great interest as displaying a new aspect of dynamical phenomena, and may help to explain still further the nature of the radiant forces, and perhaps throw light upon other questions. It is attracting much attention from scientific men, who may be expected in due time to report the results of their own reflections and experiments upon the subject.

SUNDAY AT THE CENTENNIAL EXHIBITION

THE exhibition at Philadelphia has many features of interest, one of the highest of which is that it stands out before the world in a moral and religious aspect as a tribute to the dignity, inspiration, and sacredness of conscientious and successful labor. The warriors, politicians, orators, have their honors elsewhere; the Centennial Exposition is an ovation to the "captains of industry." The multitudinous display is all due to the achievements of labor, to head-toilers and hand-toilers —the devotees and the heroes of science

and art. Each product that is gathered in that great museum has had its history, which in most cases will show a long, laborious, painful struggle after perfection, by faithful study of the laws of Nature, manifested in the operations of forces and the properties of matter. Now, these laws of Nature are the laws of God, or there are no laws of God. The divine will is disclosed in the immutable ordinances of being, and the order of the world, or there is no such disclosure to man. And to seek to know the divine will as expressed in the laws by which things are governed, and to conform action and conduct to them, is the essence of religion, or there is no religion. The denial that this great gathering of the noblest fruits of the world's thought and industry has in it a religious element, and is grounded upon a religious basis, answers to our notion of atheism and heathenism. Can we indeed assert that those who have thrown light into the dark places of Nature that the earth might be subdued, and humanity elevated, and life beautified and enriched, have not been engaged in an eminently religious service? Shall we say that the Eternal Mind, in instituting the laws of material things—chemical, physical, biological—has claims upon our religious reverence, while the human mind in discovering and applying these laws to ends of beneficence is engaged in a non-religious work? If God framed the mysterious order around us and adapted the human mind to unfold itself by studying out these mysteries, can we render him any truer homage than is implied in the consecration of thought to these studies, and in carrying on the constructive and creative works which the resulting knowledge makes possible? No! we heartily agree with Carlyle when he says, "Older than all preached gospels is that ever-enduring evangel, work is worship."

The trophies of productive knowledge and inventive genius are brought together in the vast exhibition, and what are they but witnesses that men have studied faithfully and labored well? The honesty and integrity of human effort are attested in the processes and results. The laws of Nature hold true—there is never a break in the continuities of effect—and heat, light, air, affinities, cohesions, attractions, and all the properties of elements, and the habitudes of energy, never falter for an instant, and all goes on harmoniously and successfully. Who but the irreligious can fail to recognize the solemn implications of these wonderful results; and how otherwise can they be construed by the reverent mind than as God's immediate maintenance and indorsement of the work?

The exhibition has been planned and carried out for one purpose—to be seen and to become a source of instruction and elevation to the beholders. It is designed for all classes to come and examine its treasures, and learn its lessons. The public has been taxed to establish it for purposes of public use, to be attained only by opening its gates to all comers. Its influence is undoubtedly salutary and elevating and to be every way promoted. Attendance is expensive, difficult to many, and impossible to many more. It has been enormously costly that it might be greatly valuable; and its managers are bound to leave nothing undone to carry out its design, which is to be open to the inspection of the largest possible number of people.

Yet, strange to say, the commissioners who control it have decided that it shall be shut up fourteen per cent. of the available time! They have decided to destroy one-seventh of its usefulness. They decree that one day in the week nobody shall see it. Though so extensive that much time is required for even a partial observation of it, the managers determine that the little time visitors have shall be curtailed. And, what is worse, they shut it up the very day of

all others when it would be most available to thousands. Though designed to honor labor, it is closed at the only time when multitudes of laborers have an opportunity to attend it.

And what is the reason of so apparently extraordinary and stultifying a course? After so much trouble to get it open, why do the commissioners shut it up this considerable portion of the time? The answer is, it is done in the name of religion! Religious people protest that its opening on Sunday would be a violation of the sacredness of that day, and a violation of the laws that enforce its religious observance. Influential religious bodies have passed resolutions and sent committees to Philadelphia to press this view upon the commissioners. Now, we strongly protest against this assumption that the opening of the exhibition any day of the week will be an irreligious act. The Jew may hold it wicked to visit the show on Saturday, and the Christian may hold it sinful to visit it on Sunday, and both may obey their consciences and stay away on the days they hold sacred; but to force their views upon people who think differently is not a dictate of religion but of persecuting bigotry. A century or two hence, in revising the "History of the Conflict," it will be contemptuously denied that religion was responsible for shutting up the Industrial Exhibition of 1876, against the people, and nullifying its usefulness one day in the week. It will be attributed to superstition, to theological influence and sectarian intolerance. It will be said it is a libel on religion to charge it with the narrowness and prejudice of the times when such a thing could be done.

The position of the Sunday question is simply this: there are two Sundays which we are called upon to recognize in different ways, and on totally distinct grounds, namely, the Sunday of rest from labor for secular reasons, and the puritanical Sunday, devoted to pious observances. The former is enforced by the state, on grounds of public and general utility; the latter is enforced by theological influences for reasons claiming to be religious, and stands upon an ecclesiastical basis. The secular Sunday—the Sunday of rest from labor—is an institution aiming to promote the social welfare, appealing to the sanctions of reason, and is enforced with the discretions of commonsense, and under limits which recognize the admissibility of a certain amount of labor for the general benefit. These are the considerations to which all parties appeal in advocating a day of rest, and they are the sole considerations by which legislators have any right to be moved in legally establishing it. Granting their right to ordain a general suspension of labor one day in the week, for the general good, they have no warrant to go a step beyond this in the direction of restraints upon the free action of individual citizens. They have no more authority to establish a particular religious day than to establish a particular religion. When people desist from work on Sunday, they comply with all that the state can justly require of them, and are left free to occupy themselves in any way they please, subject to the usual regulations of conduct which are in force at all times.

But ecclesiastical influence is constantly striving to turn the secular Sunday to theological account, and to invoke the interference of law with the freedom of citizens in religious matters. The history of the puritanical Sunday has been for centuries the history of meddling with the liberties of conduct, of the coercion of conscience, and the enforcement of observances on alleged religious grounds. The most innocent actions have been held as profanation of the Lord's day. All amusements were forbidden as wicked, and it was held as sinful to kindle the fire, or

dress meat, or visit the neighbors, or walk abroad in the fields. Acts intrinsically proper have been construed as crimes if done on Sunday. The absurdities of sabbatarian legislation illustrate the grossest superstitions of the past. The following statement from Cox's "Sabbath Laws" represents the character and logic of the old practices: "At Aberdeen, in the month of November, 1608, a great panic arose by reason of an earthquake which had visited the city, and as the cause of the earthquake was distinctly traceable to the custom of salmon-fishing on Sunday, the proprietors of the salmon-fishings were summoned before the Session and solemnly rebuked." This may seem ridiculous, but do we not still hear of the judgments that follow Sabbath-breaking?

And it is important to note that, when viewed even theologically, the strictness of the Puritan Sunday is without authority. If the Old Testament is appealed to, the fourth commandment forbids work with emphatic detail on the seventh day of the week, but forbids nothing else. If the New Testament is appealed to, we find Christ nowhere establishing Sunday, but entertaining such latitudinarian views on the subject as to incur the reproaches of the pietistic Pharisees for Sabbath-breaking. And in reply to their puritanical notions he curtly told them that "the Sabbath was made for man, and not man for the Sabbath." Hence it has been justly said that "Christ himself did nothing more by word or act than protest against the superstitious abuses which in course of time had grown around the Sabbath." Paul exhorts the Colossians to independence of thought upon the subject, and to let no man judge them in respect of holidays, new moons, and Sabbath-days. It is alleged that there is no evidence that the early Christians kept Sunday, or the first day of the week, with Jewish strictness, but that it was first enforced by law in A. D. 386 by the Emperor Constantine, "who attached just as much importance to his own birthday as to the day of the Lord." But the puritanical spirit grew apace. "In proportion as the Church triumphed over paganism, so did the Christian days over those of the old world. The Church naturally used every effort to secure an increased respect for the days of its own creation. And though it was not till the time of Leo the Philosopher (889–910) that Sunday field-work was forbidden by an imperial law, in reference to public games and amusements the ascetic tendencies of the Church were earlier and more generally felt. The first innovation in this direction was the law of Theodosius the Elder, which included in its prohibition not only secular business but secular amusements. Abstinence, therefore, from toil and pleasure, having thus become the law of the Christian empire, the subsequent history of Sunday resolves itself simply into an extension of the principle."

Coming down to the Reformation, we find its master-spirits still struggling against the tendency to sabbatarian intolerance. "Cranmer speaks of Sunday and other days as mere 'appointments of the magistrates,' but considers *that* a sufficient reason for their observance." Tyndale says: "As for the Sabbath, *we be lords of the Sabbath*, and may yet change it into Monday, or into any other day as we see need, or may make every tenth day a holy day, only as we see cause why; neither need we any holy day at all if the people might be taught without." Luther said: "If anywhere any one sets up its observance on a Jewish foundation, then I order you to work on it, to ride on it, to dance on it, to do anything that shall remove the encroachments on Christian liberty." Calvin, in this, was equally liberal, and set an example by playing the game of bowls on Sunday. In all these cases we note the recognition of Sunday as a human institution, subordinate

to the uses of man, while the puritanical Sunday, which represses recreations and stifles worldly enjoyments, is resisted and repudiated. The institution in its theological aspects is, therefore, destitute of any authoritative religious sanction. But, after centuries of contest between liberality and intolerance, the issue is still the same. As a day of rest from labor, Sunday is objected to by but few; and to the slave and the convict, and the millions of toil-worn operatives in factory, mine, and field, who earn their subsistence by the sweat of the brow, it is indeed a precious boon. To the multitudes doomed to a life of brutalized drudgery in barbaric times, it came as a blessed relief; and it is, perhaps, scarcely less necessary when the pressures of enterprise and competition would wear men out if no check was interposed. But the sour and gloomy Sunday of religious asceticism—the austere Sabbath of the sanctimonious Pharisee—requires to be resisted now as much as it was resisted by the founder of Christianity himself. In regard to the strict observance of Sunday, men have undoubtedly a right to do as they please under our guarantees of religious liberty; but they have no right to force their views upon others by perverting the legal day of rest to assumed religious objects, and by making it a hinderance to enjoyment and improvement on the part of those who desire so to employ it, and who are not to be judged by others in their manner of doing it.

It is objected to the opening of the exhibition on Sunday that it would involve the labor of many in attending to its operations, running trains, etc. But even the superstitious Jews had sense enough to interpret the fourth commandment as allowing works of necessity. A certain amount of Sunday labor is everywhere recognized as unavoidable, and as long as cooking, the running of Sunday cars and carriages, police surveillance, and the distribution of the mails, are carried on in Philadelphia under Pennsylvania laws, the objection to opening the exhibition because it would violate the law against Sunday labor is futile.

But we insist upon keeping the argument upon its highest grounds. We showed at the outset that the character and influence of such an exhibition are not only in the highest degree moral and salutary, but are also essentially religious; its opening every day of the week is therefore defensible on strictly religious grounds. We have furthermore shown that the religious reasons offered, for shutting it up on Sunday, are baseless. The considerations urged for closing are hence exactly those which require it to be free of access to the public—in other words, religion requires the opening. If it be alleged that the people would not see these higher meanings of the objects displayed, that only shows the defects of their religious training; and that there is all the more need of insisting upon this higher office of the exhibition. And if they are thus insensible to the moral and religious significance of so grand a collection of the noblest and most perfect products of human thought and skill, what more proper than to point out to them the elevated lessons that they teach? And if, instead of demanding that the exhibition shall be suppressed one day in the week, as if it were a public nuisance, the committees who have taken so deep an interest in the matter had asked the commissioners to arrange for religious services in one of the great halls, and to provide for discourses designed to bring out the higher instructiveness of the occasion and the demonstration, we think that they would have much better subserved the interests of true religion. The religious lesson that the commissioners have now lent themselves to inculcate is that people shut out from the Centennial buildings shall go to other buildings to think upon God; and that, therefore, the Centen-

nial collection is a mere godless, sordid, anti-religious affair. But the people do not go to the appointed places of religious assembly. They crowd around the grounds by thousands, and occupy themselves in drinking at the saloons, and in cursing the bigotry of the management which forbids them to look upon the objects within, on the day that the State forbids them to work.

We fear, however, that any considerations of principle will be wasted upon the commissioners. The reasons they avow for forbidding entrance to the grounds on Sunday are not of a very elevated kind. In the report of the majority, after referring to the legislation of the country to prevent "secular business operations" on the "Christian Sabbath," they say: "Any action of this commission which is in conflict with the public sentiment expressed in these laws and in their practical observance will, in the judgment of your committee, so shock the moral sense of the country that it will jeopardize the success of the Centennial Exhibition, and turn the most powerful agencies throughout the land from active support to decided opposition. Your committee, therefore, recommend that the commission adhere to the policy which has heretofore governed its actions on this subject." It is not the "moral sense" of the community that would be shocked by opening the exhibition on Sunday. The "powerful agencies throughout the land" that would oppose it by deterring people from attendance on week-days, because those who wish it were admitted on Sunday, are not impelled by "moral sense," but by a narrow spirit of intolerance which is as immoral as the spirit of any other tyranny. The commissioners are of course bound to do every proper thing to insure the success of the exhibition; but they are not bound to eliminate all higher considerations from their conception of "success." We could wish them a little more elevation of view on this great national occasion; and in regard to their Sunday policy a little more of the spirit of Christ and Paul, Tyndale and Luther; a little more, indeed, of the genuine "spirit of Seventy-six."

LITERARY NOTICES.

THE ANCIENT RÉGIME. By HIPPOLYTE ADOLPHE TAINE, author of "A History of English Literature," "Italy," etc. Translated by JOHN DURAND. New York: Henry Holt & Co. Pp. 421. Price, $2.50.

ALTHOUGH M. Taine has made his reputation as a literary man, he must be credited with a genuine feeling for philosophical inquiry, and if not a scientist in the thorough sense, he nevertheless aspires to carry on his inquiries by scientific method. The present work is written from this point of view. Its author takes the modern standpoint in the study of history, and recognizes the futility of politics, when not guided by the principles of national development. His attitude of mind, and the spirit which he has brought to his task, are so admirably presented in the following passage from his preface, that we transcribe his own words. After stating that in 1849 he was twenty-one years old, and was called upon to vote, he remarks:

"It was optional with me to be royalist or republican, democrat or conservative, socialist or Bonapartist; I was neither, nor even anything at all, and, at times, I envied so many people of faith who had the good fortune to be something. After hearing the various doctrines I felt that there was undoubtedly some void in my mind. Motives valid for others were not so for me; I could not understand how in politics one could make up his mind according to his predilections. Peremptory advisers constructed a constitution as if it were a house, according to the most attractive, the newest, and the simplest plan, holding up for consideration the mansion of a marquis, the domicile of a bourgeois, a tenement for workmen, barracks for soldiers, the communist phalanstery, and even a camp for savages. Each one asserted of his model, 'This is the true abode of man, the only one a man of sense can dwell in.' In my opinion, the argument was weak; personal fancies are not authorities. It appears to me that a house might not be built for the architect, nor for itself, but for the owner and occupant. To ask the opinion of the owner, to submit plans

to the French people of its future dwellings, was too evidently a parade or a deception: in such cases the question is tantamount to the answer, and, besides, had this answer been unconditioned, France was scarcely more at liberty to give it than I was; ten million ignorant men cannot constitute a wise one. A people on being consulted may indeed tell the form of government they like, but not the form they need; this is possible only through experience; time is required to ascertain if the political dwelling is convenient, durable, proof against inclemencies, suited to the occupant's habits, pursuits, character, peculiarities, and caprices. Now, as proof of this, we have never been content with our own; within eighty years we have pulled it down thirteen times in order to rebuild it, and this we have done in vain, not having yet found one that suits us. If other people have been more fortunate, if in other countries many political institutions are durable and last indefinitely, it is because they have been organized in a peculiar manner, around a primitive and massive nucleus, supported on some old central edifice, many times repaired, but always preserved, enlarged by degrees, adapted and modified, according to the wants of the inhabitants. None of them were built at one stroke on a new pattern, and according to the provisions of reason alone. We must perhaps admit that there is no other way of building permanently, and that the sudden concoction of a new constitution, suitable and durable, is an undertaking surpassing the forces of the human mind. In any event, I came to the conclusion that if we should ever discover the one we need it will not be by the means in practice. The point is to *discover* it, if it exists, and not to put it to vote. In this respect our preferences would be fruitless; Nature and history have chosen for us in advance; it is for us to adapt ourselves to them as it is certain they will accommodate themselves to us. The social and political mould into which a nation may enter and *remain* is not subject to its will, but determined by its character and its past."

From this point of view, M. Taine came to the conclusion that his country needed, first of all, to be studied systematically, and the present work is the first of a series which together are designed to constitute a philosophic study of modern France. The "Ancient Régime," the volume now published, is devoted to the pre-Revolutionary period, and is to be followed by a work on the French Revolution, which will in turn be preparatory to a third, on the "New Régime," designed to interpret recent and contemporary France. The enterprise will be executed with the undoubted ability that distinguishes this brilliant and versatile author, and will permanently identify his name with modern French history. At any rate, the present book is instructive and fascinating to a remarkable degree. It is at the same time a vivid and life-like picture of French society anterior to the Revolution, and a subtile and comprehensive analysis of the forces at work in it, that issued in the revolutionary outbreak. A marked characteristic of the work is the freshness of a large portion of its materials, resulting from the author's indefatigable researches among hitherto unexplored masses of original correspondence, documents, and records.

THE WARFARE OF SCIENCE. By ANDREW DICKSON WHITE, LL. D. New York: D. Appleton & Co. Pp. 151. Price, cloth, $1; paper, 50 cents.

THE admirable lecture of President White upon this subject, which was published in THE POPULAR SCIENCE MONTHLY for February and March, is now issued in a separate form, with important additions, by the author. Although a small book, it covers broad ground, and treats the subject in a decisive way. The thesis maintained is this: "*In all modern history, interference with science in the supposed interest of religion, no matter how conscientious such interference may have been, has resulted in the direst evils both to religion and to science, and invariably. And, on the other hand, all untrammeled scientific investigation, no matter how dangerous to religion some of its stages may have seemed, for the time, to be, has invariably resulted in the highest good of religion and of science.*" In working out the proof of these propositions, President White has traversed an extensive field of historical resources, dealing successively with the rise and progress of geography, astronomy, chemistry and physics, anatomy and medicine, geology, political economy, agriculture and engineering, and scientific instruction. The whole discussion has been carefully gone over, and much amplified in its present form. In his preface the author says: "I have now given it careful revision, correcting some errors, and extending it largely by presenting new facts and developing various points of interest in the general discussion. Among the subjects added or rewrought are: in astronomy, the struggle of Galileo and the retreat of the Church after its victory; in chemistry and physics, the compromise between science and theology

made by Thomas Aquinas, and the unfortunate route taken by science in consequence; in anatomy and medicine, the earlier growth of ecclesiastical distrust of these sciences; in scientific education, the dealings of various European universities with scientific studies; in political and social science, a more complete statement of the opposition of the Church, on scriptural grounds, to the taking of interest for money; and in the conclusion, a more careful summing up."

The distinguishing feature of this little volume, and which will make it eminently valuable and useful at the present time, is its copious and careful notes, which give authoritative support to the argument. Nothing important is left to rest upon mere assertion. The battle that Science has had to fight from the beginning, and without remission, with ignorance, prejudice, and intolerance, inspired and directed by ecclesiastical influence, is vividly delineated in the text, and the positions taken are so fortified by citations from works of the highest character as to leave little room for further controversy. That the history of Science has been throughout a struggle with the theologians, and that the Bible has been used by devout believers in its infallible inspiration to crush out the results of scientific inquiry, are perfectly well known; while that science is still dreaded and denounced on religious grounds, and that the Bible is still extensively appealed to against its conclusions, are now so obvious that there is certainly no reason for doubting its employment in the same way, in less enlightened times. But there are so many who are inclined to forget, and belittle, and explain away the uglier features of the past conflict, that it becomes necessary to array the evidence of it in book and page, chapter and verse, as President White has done. Nothing is to be gained, at any rate, by ignoring historic truth, and bigotry and superstition still offer too vigorous a resistance to the advance of rational inquiry to make it desirable that we should quite forget the painful lessons of the past.

DIE HUNDERTJÄHRIGE REPUBLIK. Von JOHN H. BECKER. Augsburg: Lampart & Co. Pp. 440.

THE author of the "Centennial Republic," during a sojourn of several years in the United States, was a critical observer of our social and political life. The result of his observations is a merciless exposure of all the vices and defects of republican institutions as they exist in this country. The work is in reality a pamphlet intended to influence the minds of Germans living at home, and to dissuade them from emigrating to the United States. Mr. Becker has three chapters on the condition of the working-class; several chapters on politics and government, rings, carpet-baggery, corruption, the lobby; finally, he treats of the family, education of children, and a number of other subjects. The author is an advocate, and does full justice to the cause he defends; the brighter side of American life is not his concern.

FRENCH POLITICAL LEADERS. By E. KING. *Also*, GERMAN POLITICAL LEADERS. By HERBERT TUTTLE. Pp. 264. New York: Putnams. Price, $1.50 each.

THESE two volumes are numbered respectively III. and IV. in Putnam's series of "Brief Biographies," designed to acquaint the American public with the characters and services of eminent politicians and statesmen abroad. In vol. iii. we have sketches of twenty-three of the foremost political leaders of France, and in vol. iv. of nineteen men prominent in the political life of Germany. Both Mr. King and Mr. Tuttle have enjoyed the advantage of personal acquaintance with several of the subjects of their biographies; in all cases they have had the best opportunities for studying the men whose lives they describe. They are no transcribers of biographical notes and dates, their aim being rather to portray character than to inform the reader of the dry and impertinent details of a man's career.

HISTORY OF THE UNITED STATES. By J. A. DOYLE. New York: Holt. Price, $1.40.

THIS is beyond question the best manual of the history of the United States that has yet been written. The style is plain and marked by directness; and the author usually assigns to events their true proportions, as viewed from the standpoint of the impartial historian. Four graphical maps exhibit—1. The changes in territory; and, 2. The distribution of population in 1790, 1830, and 1870.

THE CHILDHOOD OF RELIGIONS: EMBRACING A SIMPLE ACCOUNT OF THE BIRTH AND GROWTH OF MYTHS AND LEGENDS. By EDWARD CLODD, F. R. A. S. New York: D. Appleton & Co. Pp. 288. Price, $1.25.

THE author of this book published, two or three years since, a little volume entitled "The Childhood of the World," in which he presented, in a familiar way, designed for perusal by the young, the modern doctrine of the antiquity of the world, and something of that which is now regarded as known concerning the primitive condition of man. The success that attended his former undertaking has led him to break into another and a kindred field, and to present, in a popular and readable form, what is considered to be known in relation to primitive religions. The author regards the two works as but parts of one argument, and the present volume as the natural and necessary outgrowth of the former. Of the need and purpose of such an exposition he remarks, at the opening:

"The question which forces itself upon all who are interested in the education of the young is what they shall be taught regarding the relation of the Bible to other sacred scriptures, and to the declarations of modern science when they fail to harmonize with its statements; and it is as a humble contribution to the solution of that question that the present and preceding volumes have been written. In an age which has been truly characterized by a leading thinker as one of 'weak convictions,' it seems to me incumbent on those who, in accepting the conclusions to which the discoveries of our time point, regard the inevitable displacement of many beliefs without fear, because assured that the great verities remain, to be faithful to their convictions, and to show that the process of destruction is removing only the scaffolding which, once useful, now obscures the temple from our view. In the absence of any like elementary treatise upon subjects regarding which much ignorance and apathy prevail, and the treatment of which is at present confined to works for the most part high-priced, and not always accessible, I hope that this book may not be regarded as needless, however far it falls short of the requirement which appears to me to exist, and which it ventures to temporarily supply."

The book is very plainly written, and gives a great deal of interesting information about myths and legends of the creation, religious beliefs of the Aryan or Indo-European nations, the religion of the ancient and modern Hindoos, Buddhism, and the ancient religions of Persia, China, and the Semitic nations. Much is said upon these subjects nowadays by learned men, and Mr. Clodd's volume is a good popular introduction to this field of literature.

THE PHYSICAL BASIS OF IMMORTALITY. By ANTOINETTE BROWN BLACKWELL. New York: G. P. Putnam's Sons. Pp. 324. Price, $1.50.

THIS volume is an intrepid attempt to establish the doctrine of personal immortality on the scientific basis of modern physical theories. The indestructibility of matter and force, and the existence of atoms or units, are the principles Mrs. Blackwell employs as the foundation of her argument. We cannot here analyze it, but will give the author's standpoint in her own words:

"It must be a part of my effort to offer sufficient evidence that actual indestructible centres of force do exist in Nature; and that no force is or ever can be, during the present order of natural events, separated from its own individual centre of activities. If this form of the atomic theory can be proved; if atoms can be shown to exist, and to persist in the midst of all changes, these atoms then become the unshaken basis of a personal immortality. We have only to further show that there are centres of atomic force, some of whose modes of energizing are sentient modes, and the whole case will be gained" (page 89).

"Mind is matter and something more. *Every mind is an indestructible material unit, constituted by allied force and extension, jointly conditioned with sentient force or consciousness.* The whole is an indivisible and immortal conscious personality" (page 175).

WILLIAM WHEWELL, D. D., MASTER OF TRINITY COLLEGE, CAMBRIDGE. AN ACCOUNT OF HIS WRITINGS, WITH SELECTIONS FROM HIS LITERARY AND SCIENTIFIC CORRESPONDENCE. By I. TODHUNTER, M. A., F. R. S. Two Vols., 416 and 439 pp. New York: Macmillan & Co. Price, $9.

WE have long waited for a life of Dr. Whewell, and although we have not found it in these volumes, in the usual sense of the biography, yet we have here what may be called a history of his intellectual life, as disclosed in the informal and fragmentary passages of an extensive correspondence. Sir John Herschel has said of Dr. Whewell that "a more wonderful variety and amount of knowledge in almost every department of human inquiry was perhaps never in the same interval of time accumulated by any man." Of this, his numerous and learned publications bear ample witness, and it is of course from these that

the intellectual character of the man is to be properly deduced. But our interest in him is greatly heightened by the glimpses of a strong personality, which these volumes reveal in his free and extensive intercourse with the intellectual celebrities of the time. We have no space for illustrations of the quality of these most readable books, but the following reference to Dr. Lardner will give a sample of their general spiciness:

"Mr. Herschel's discourse" (on natural philosophy) "was published in Lardner's 'Cabinet Cyclopædia,' and he afterward contributed to the same series an elementary 'Treatise on Astronomy.' Prof. Whewell was not quite satisfied with the channel which his eminent friend thus accepted for his writings. Dr. Lardner was a man of scientific attainments, and of considerable ability for popular exposition; his importunity in urging the fulfillment of the promises which he obtained of coöperation in his 'Cyclopædia,' and his name Dionysius, which it was conjectured he had himself modified from the more familiar Denis, naturally led to the appellation *tyrant*, which was given to him in a good-tempered manner by Southey and other literary men of the period. He made various attempts to induce Prof. Whewell to join his staff, and in particular during the present year wished to engage him to write on political economy; but the applications were in vain. Prof. Whewell, perhaps, mentioned the matter to Mr. Jones, as we may conjecture from a sentence in a letter from him: 'I should like to write a treatise for the tyrant if he would wait two or three years, but he shall not have the *prémices* of my speculations.'"

THE CHRIST OF PAUL; OR, THE ENIGMAS OF CHRISTIANITY. By C. REBER. New York: Somerby. Price, $2.00.

THE principal topics considered in this volume are, the influence of the Essenes and Therapeutæ on the development of the Christian system; the origin of the four Gospels; the influence of Irenæus on Christian beliefs; the dogma of the Trinity; the origin of the Episcopate and of the Papacy; the miracles attributed to Christ, the Apostles, and their successors.

CONNECTION OF METEOROLOGY WITH HEALTH. By WILLIAM BLASIUS.

IN this paper the author strives to assign a philosophical reason for "the well-known fact" that, during all ages, cities, where topographical impediments do not interfere, extend, as a general rule, from east to west, and that the wealthiest people are always in the advance.

LESSONS FROM NATURE, AS MANIFESTED IN MIND AND MATTER. By ST. GEORGE MIVART, Ph. D., F. R. S. Pp. 462. New York: D. Appleton & Co. Price, $2.

THE title of this book is somewhat misleading. We should expect to find in its pages a cool, didactic statement of the result of observations and studies in natural history, perhaps, or in some of the familiar aspects of Nature. But, instead of simple lessons or inculcations from natural things, presented in a quiet and instructive form, we have a book full of rancorous controversy and bitter polemics. Mr. Mivart has achieved some reputation as an anatomist and biologist, and is by no means destitute of expository power, but the discussions in this volume show that he is more a theologian than a scientist, more a bigot than a philosopher, and more fond of fighting than teaching. He makes a series of vindictive assaults upon men with whom he does not agree, and then names the result "Lessons from Nature." A writer in the *Quarterly Journal of Science* administers to Mr. Mivart a well-merited castigation for his unscrupulous course in dealing with contemporary thinkers, and we publish a portion of the article under the title of "Bigotry and Scientific Controversy." The writer treats him unsparingly, but we think justly, and condemns in terms of merited severity the practice, not yet extinct, of appealing to the *odium theologicum*, which "in its most malignant form pervades the entire book."

"Lessons from Nature" is a discussion of the tendencies of modern theories which are associated with the names of Darwin, Spencer, Mill, Helmholtz, Huxley, Lewes, and others, which are variously characterized by this author as immoral, irreligious, materialistic, and atheistic. The course of thought is more metaphysical than physical, and the volume derives but little value from the scientific acquirements of the writer. Indeed, he had already told us in his "Genesis of Species" all that he has to say in opposition to the views of Darwin, and here it is only restated with the garnish of abuse and invective. But, although himself committed in the "Genesis of Species" to the doctrine of Evolution, and saying, as he does at page 16, "the prevalence of this theory need alarm no one, for it is, without

any doubt, perfectly consistent with the strictest and most orthodox Christian theology," yet his present book is a battle with the Evolutionists, and the consequences of the theory, and in the interest of Catholic orthodoxy. And the champion proves to be not a whit too good for the cause he represents. In the survivals from savagery the same spirit only changes its instruments —the tomahawk is replaced by the pen. Those who delight in vicious polemics will find Mr. Mivart's volume an unusual treat.

A NEW ENCYCLOPÆDIA OF CHEMISTRY, THEORETICAL, PRACTICAL, AND ANALYTICAL, AS APPLIED TO THE ARTS AND MANUFACTURES. By Writers of Eminence. Illustrated with numerous Steel-Cuts and Engravings. Complete in 40 Parts. 50 cents each. Philadelphia: Lippincott & Co.

WE have received five numbers of this work, which promises to be valuable and exhaustive. It is constructed upon the basis of the elaborate work, "Chemistry as applied to the Arts and Manufactures," by the late Dr. Muspratt, which was published twenty years ago. But twenty years antiquates a chemical book, especially when it deals with the application of science to the arts. Numerous and important improvements in chemical manufacture have been made within the last quarter of a century, which make new statements indispensable to those who are concerned with practical processes. The thoroughness of treatment adopted in this work is illustrated by the fact that nearly the whole of the first part is devoted to acetic acid and its salts. Alcohol occupies the second part; and alum, ammonia, aniline dyes, antimony, and arsenic, are treated with a corresponding fullness. In their prospectus the publishers remark: "Convinced that the infinite variety of subjects now embraced in such a work could be adequately treated by no one writer, however learned or painstaking, the assistance of the leading chemists of the present day has been secured, as well as of writers who are practically acquainted with all the details of our great manufactures." But no names are given, either of editor or collaborators. Something would, no doubt, be gained by knowing to whom the execution of so large an enterprise has been intrusted, but we admire the pluck that puts the work forth—and a subscription-book at that—without the parade of names, and lets it go squarely upon its merits. It deserves to succeed.

ANGOLA AND THE RIVER CONGO. By J. J. MONTEIRO. With Maps and Illustrations. Pp. 354. New York: Macmillan & Co. Price, $2.50.

WE have not seen lately a more thoroughly interesting and instructive book of travels than this. The author spent several years in the country he describes, and his travels extended from the Congo River on the north, down the coast through about 10° of latitude. Most of his time was spent among the trading-towns at the mouths of rivers and along the coast, but he had frequent opportunities of studying the simple-minded savages of the interior. He found the natives kindly disposed if well treated. He was accompanied by his wife in his journeys, to whom the book is dedicated in a few touching and appropriate words. His travels seem to have been connected with a discovery made by himself in 1858, that the bark of the baobab-tree is of value in the making of paper. Many parts of the regions visited were covered by forests of this tree.

Among the natives fetichism prevails everywhere. Anything, as a tree, or animal, or an old rag, may be a fetich. No body dies a natural death, but is fetiched.

These people are not degraded, but represent a low stage of culture. They are undeveloped—not distinguished so much by the presence of positively bad as by the absence of good qualities. They are strangely wanting in the feelings:

"The negro knows not love, affection, or jealousy. I have never seen a negro manifest the least tenderness to a negress. They have no words or expressions in their language indicative of affection or love. Their passion is purely of an animal description, without affection. Mothers rarely play with or fondle their babies; as for kissing them, such a thing is not known; yet I have never seen a woman grossly neglect her child."

The book abounds with information concerning the climate, productions, physical geography, and general natural history of the region, and is a treasure equally to the general reader and to the student of this part of the vast African wilderness.

A PRACTICAL TREATISE ON ROADS, STREETS, AND PAVEMENTS. By Q. A. GILLMORE, A. M. Pp. 258. New York: D. Van Nostrand. Price, $2.

A MUCH-NEEDED and most excellent little manual. There is no better measure of civilization than the state of the highways in city or country, and judged by that standard the American people are not much advanced. Bad roads prevail—roads badly laid out, badly constructed, and kept in bad order—and, while this general badness is an enormous burden upon the community, involving waste of horse-flesh, vehicles, time, and obstruction of business, there is still a degree of ignorance concerning the mechanics of the subject that is surprising among a people who make such large pretensions to enterprise. There are well-established principles in road-laying, road-making, and road-management, the violation or neglect of which entails such serious losses that it is a matter of public economy to wake up any community to the importance of the subject. General Gillmore's book gives the latest information regarding it, within moderate limits, and he thus states the leading objects that have been kept in view in its preparation:

"1. To give within the compass of one small volume such descriptions of the various methods of locating country roads, and of constructing the road and street coverings in more or less common use at the present day, as will render the essential details of those methods, as well as certain improvements thereon of which many of them are believed to be susceptible, familiar to any intelligent non-professional reader. 2. To make such practical suggestions with respect to the selection and application of materials, more especially those with the properties and uses of which builders are presumed to be the least acquainted, as seem needful in order to develop their greatest practical worth and realize their greatest endurance. 3. To institute a just and discriminating comparison of the respective merits of the several street pavements now competing for popular recognition and favor, under the varying conditions of traffic, climate, and locality, to which they are commonly subjected."

USES OF A TOPOGRAPHICAL SURVEY OF NEW YORK. By JAMES I. GARDNER.

THE uses of a topographical survey of the State, as set forth in this paper, are as follows: 1. Such survey is a necessary basis for equalizing taxation; 2. It will establish imperishably every property boundary in the State; 3. It will make it possible to describe correctly the area of real estate conveyed by a deed; 4. It will afford facilities for proper plans of suburban drainage and water-supply, and extensions of village streets and country roads; 5. It will furnish a basis for a scientific survey of the State's resources.

THE AMERICAN STATE AND STATESMEN. By W. G. DIX. Boston, Estes & Lauriat. Price, $1.50.

IN his preface the author asks the question, "Have we not been trying to get along somehow for nearly a hundred years without any principle of government?" If so, it is full time to discover a principle of some kind. From the titles of two or three chapters, such as "Christianity the Inspirer of Nations," "America a Christian Power," "Materialism the Curse of America," it would appear that the author's prescription for all our political ills is Christian statesmanship. And, when the nation has been saved, we must head a grand crusade against Mohammedan sovereignty in Eastern Europe, Western Asia, and Northern Africa!

THE BIBLE AND SCIENCE. By J. WEISS. *Also*, THE SYMPATHY OF RELIGIONS. By T. W. HIGGINSON.

THESE are tracts published by the Free Religious Association, Boston. They are intended to popularize the ideas and aims of a body of thoughtful men and women, and are sold at the low price of $3.00 per hundred copies. The tracts already published are four in number, including, besides the two named above, one on "Taxation of Church Property," by James Parton, and one on "Transcendentalism," by the late Theodore Parker.

NOTES ON THE YUCCA-BORER. By C. V. RILEY, Ph. D. Pp. 23. St. Louis: R. P. Studley.

THE roots or subterranean trunks of yuccas are often found to be hollowed out along the axis; this tunneling is the work of the yucca-borer (*Megathymus yuccæ*). In the paper before us, Prof. Riley gives the results of his studies upon this insect. He is inclined to regard the yucca-borer as the representative of an ancient type from which are derived on the one hand the *Castnians*, on the other the *Hesperians*.

EXERCISES IN ELECTRICAL AND MAGNETIC MEASUREMENT. By R. E. DAY, M. A. Pp. 130. London: Longmans, Green & Co.

THIS little manual is intended for the use of students commencing a course of laboratory practice, or preparing themselves for actual work in connection with electric telegraphy. The author employs almost exclusively the nomenclature and system of units approved by the committee of the British Association, but he also gives exercises in the conversion of these units into the units of various other systems, and *vice versa*.

FIRST ANNUAL REPORT OF THE JOHNS HOPKINS UNIVERSITY.

THIS Report contains the Statement of the Trustees, the Report of the President of the University, Daniel C. Gilman, a letter from P. R. Uhler on Collections in Geology and Natural History, and a Preliminary Announcement of courses of study, fellowships, scholarships, etc.

PUBLICATIONS RECEIVED.

The Wages Question. By Francis A. Walker. New York: Holt & Co. Pp. 428. Price, $3.50.

Geological and Geographical Survey. Report of F. V. Hayden for the Year 1874. Washington: Government Printing-Office. Pp. 515.

Annual Record of Science and Industry for 1875. By Spencer F. Baird. New York: Harpers. Pp. 946. Price, $2.

Elements of Psychology. By H. N. Day. New York: Putnams. Pp. 248. Price, $1.50.

Spirit Invocations. By P. A. Putnam. Boston: Colby & Rich. Pp. 256. Price, $1.25.

The Historical Jesus of Nazareth. By M. Schlesinger, Ph. D. New York: Somerby. Pp. 98. Price, $1.

High Masonry Dams. By J. B. McMaster, C. E. New York: Van Nostrand. Pp. 132. Price, 50 cents.

Geology of Portions of our Western Territory. By G. K. Gilbert. Pp. 342.

The Geology of Route from St. George, Utah, to Gila River, Arizona. By A. R. Marvine. Pp. 30.

The Geology of Portions of our Western Territory. By E. E. Howell. Pp. 70.

Oxidation Product of Glycogen. By R. H. Chittenden. New Haven: Tuttle & Co., Printers. Pp. 10.

A Gigantic Bird. Pp. 5. *Also*, Vertebrate Fauna of the Eocene of New Mexico. By E. D. Cope. Pp. 8.

The Public-School Question. Two Lectures. Boston: Free Religious Association. Pp. 100. Price, 20 cents.

Inauguration of President Gilman. Baltimore: John Murphy & Co. Pp. 64.

Valedictory Address of Medical Faculty. By Dr. T. A. Atchison. Nashville University. Pp. 15.

International Medical Congress, 1875. By Dr. G. W. Wells. New York. Pp. 12.

Proceedings of the Kings County Medical Society, Brooklyn. Pp. 40.

Natural History of Kerguelen Island. By Dr. J. H. Kidder. Part II. Washington: Government Printing-Office. Pp. 122.

Poughkeepsie Society of Natural Science. Pp. 41.

Report of the Overseers of the Poor of Lowell. Pp. 49.

Bulletin of the Nuttall Ornithological Club, Cambridge, Mass.: H. B. Bailey, 13 Exchange Place, Boston. Pp. 28. Quarterly, $1 per year.

Manual of the Apiary. Pp. 59. *Also*, Injurious Insects of Michigan. Pp. 48. By Prof. A. J. Cook, Michigan Agricultural College.

Supposed Changes in the Nebula M17 = h. 2008 = G. C. 4403. By E. S. Holden. Pp. 20. From *American Journal of Science.*

Eozoön Canadense at Côte St. Pierre. By J. W. Dawson. Pp. 10. From *Journal of the Geological Society.*

Fundamental Principles of Science. By L. Hyneman. Boston: Colby & Rich. Pp. 29.

Fishes of the Bermudas. By G. Brown

Goode. Washington: Government Printing-Office. Pp. 82.

Tracts on Labor and Money Questions. Nos. III. and VI. By William Brown.

MISCELLANY.

Destruction of the Buffalo.—The average annual destruction of buffaloes during the last thirty or forty years is estimated by a writer in the *Penn Monthly* at between three and four millions. During the season of 1872–'73 no less than two thousand hunters, it is said, were engaged in hunting the buffalo along the line of the Atchison, Topeka & Santa Fé Railroad alone. By these men at least 250,000 buffaloes were slain, simply for their hides, the carcasses being left untouched on the plains. At this rate, the bison will have utterly disappeared before many years, unless Government interferes to prevent this wasteful slaughter. As yet, neither the central Government nor any of the States have taken any effectual measures to prevent the extermination of the noble animal. The author of the article in the *Penn Monthly* suggests that the traffic in hides might easily be checked and controlled by law. The killing of buffaloes should be restricted, he says, to certain seasons of the year, and the destruction of the females and young wholly prohibited. Further, he would have it made a grave offense to kill a buffalo at any time wantonly, or without properly utilizing it. Then, certain portions of the public lands now within the range of the buffalo might be made a preserve, wherein no buffaloes should on any condition be killed.

Distribution of the Rocky Mountain Locust.—Prof. Riley fixes the southern limit of the Rocky Mountain locust's ravages at the 44th parallel of latitude and the eastern limit at the 103d meridian. The conditions preventing the permanent settlement of this insect in regions outside of the above limits are considered by Prof. Riley in his eighth annual report on the insects of Missouri. The native home of this locust he takes to be the higher treeless and uninhabitable planes of the Rocky Mountains—a sub-alpine habitat with dry and attenuated atmosphere. Now, a migration of insects accustomed to such conditions into a more dense and humid atmosphere must prove fatal to them. But another barrier to their permanent multiplication in the more fertile country to the southeast is found in the greater duration there of the summer season. As with annual plants, so with insects (like this locust) which produce but one generation annually and whose active existence is bounded by the spring and autumn frosts, the duration of active life is proportioned to the length of the growing season. "Hatching late and developing quickly in its native haunts, our Rocky Mountain locust, when born within our borders (and the same will apply in degree to all the country where it is not autochthonous), is in the condition of an annual northern plant sown in more southern climes; and just as this attains precocious maturity and deteriorates for want of autumn's ripening influences, so our locust must deteriorate under such circumstances. If those which acquired wings in Missouri early last June had staid with us long enough to lay eggs, even supposing them capable of doing so, those eggs would have inevitably hatched prematurely, and the progeny must in consequence have perished."

Fight between a Mouse and a Scorpion.—Frank Buckland, having witnessed the rare spectacle of a combat between a mouse and a scorpion, gives in *Land and Water* the following description of the fight: "The mouse having been dropped into the jar containing the scorpion, the battle at once commenced by the scorpion assuming the offensive. He made a lunge with his sting and struck the mouse. This woke up the mouse, who began to jump up and down like jack in the box. When he became quiet, the scorpion again attacked the enemy, with his claws extended like the pictures of the scorpion in 'The Signs of the Zodiac.' He made another shot at the mouse, but missed him. I then called 'Time!' to give both combatants a rest. When the mouse had got his wind, I stirred up the scorpion once more, and, as 'the fancy' say, 'he came up smiling.' The mouse during the interval had evidently made up his mind that he would have to fight, and not strike his colors to a

scorpion as he would to a cat. When, therefore, the scorpion came within range, the mouse gave a squeak and bit him on the back; the scorpion at the same moment planted his sting well between the mouse's ears on the top of his head. The scorpion then tried to retreat, but could not, for one claw had got entangled in the fur of the mouse. The mouse and scorpion then closed, and rolled over each other like two cats fighting, the scorpion continually stabbing the mouse with his sting, his tail going with the velocity of a needle in a sewing-machine. When the scorpion got tired, the mouse got hold of his tail with his teeth and gave it a sharp nip. The mouse seized the opportunity, and immediately bit off two of the scorpion's side-legs. He then retired, and began to wash his face. I had expected, of course, that the poison of the scorpion would have killed the mouse, but he didn't seem a bit the worse for it. When I examined him the next morning he was quite lively and well, and had nearly eaten up the whole of the scorpion for his breakfast. Of course I rewarded the mouse for his plucky conduct by giving him some milk, and by letting him go in a place where it was not likely the cat would find him."

Labor at the South African Diamond-Fields.—The exploitation of the diamond-fields of South Africa promises to exert a mighty influence on the native populations living north of Griqualand. No sooner had the demand for labor arisen at the diggings than vast numbers of the races known as Mahawas, who live between the twenty-third and twenty-fourth parallels of south latitude, poured down from the country bordering on the Limpopo, and eagerly took service with the diggers. "They came in large bodies," says Mr. J. B. Currey, secretary to the government of Griqualand West, "often as many as two thousand in a month, arriving in a wretched state of emaciation." They wear no clothing save a cincture round the loins. They stay about six months, and then they are sleek, well-made, and often powerful men. They are very thrifty, and generally have from eight to ten pounds in money when the time for their departure arrives. This they expend in purchasing guns, powder, and lead, old military uniforms, beads, brass wire, and perhaps a little food, and set out for their own country, each man staggering under his burden. From the Mahawas the tidings of work and pay at the diamond-fields spread to other tribes living farther north, and in the early part of 1874 appeared groups of Makalakas from the great plains in latitude 20°, a race said to be without chiefs or laws or organization of any kind whatever. Still, degraded as is their condition, they seem to possess some remains of a more civilized state, and to show signs of an intelligence superior to that of the Mahawas. Parties of these people continued to arrive during 1874 and 1875, and in the middle of the latter year came the first party of the Maschonas, large, powerful, jet-black men, from latitude 18° on the southern bank of the Zambezi.

Remarking upon this curious movement of the natives, Mr. Currey observes:

"And this great stream of native labor returns, after a few months, to the great ocean from which it flowed, bearing with it, as is inevitable, some traces of the strange lands through which it has passed, and some tinge of the things with which it has come in contact. We cannot prevent this, even if we would. For good or for evil these natives have tasted of the tree of knowledge, and know that they are naked. They go back, with something to tell, and the strange stories that must be repeated from hut to hut and village to village, the distorted accounts which must be spread of our religion and our laws, our virtues and our vices, our manners and customs, will produce results greater than any that all the missionaries of Europe could effect in a century. Events novel and rapid, which we have had no power to control, have unexpectedly placed us in immediate communication with new tribes, and our connection with them entails results which no indifference can ignore, and from which no timidity can escape."

Natural History of the American Antelope.—From an interesting paper in the *American Naturalist*, by Judge Caton, we select the following notes upon the natural history of the American antelope: The animal is not a native of the Old World, and is confined to a very limited portion of the New. In size the prong-buck, or American antelope, is considerably smaller than the Virginia deer, the adult male rarely exceeding four feet in length from tip to tip, and three feet in height to the top of the shoulder. The hairs of this animal differ from those of most of the hollow-horned ruminants,

and possess the extreme characteristics of those of the deer. They are hollow except near the roots and extreme points, and are filled with a sort of light pith, like that found in the quill of the turkey. The hairs are non-elastic and fragile, in this respect resembling more those of the caribou than of any other quadruped. The entire absence of the hind or accessory hoof distinguishes the prong-buck from both the deer and the antelope. A very important feature of the prong-buck is its glandular system, from which is emitted a rather pungent odor.

The eye of the prong-buck is exceptionally large—much larger than that of the deer, the ox, or the horse. The entire exposed part of the orb is intensely black, with a mild and gentle expression. The animal is the swiftest-footed of all known quadrupeds, but it cannot continue the race at high speed for a great length of time, although for a few miles or a few minutes its career seems like the flight of a bird. While it can make astonishing horizontal leaps, even from a standing position, it cannot or will not make high vertical leaps. The author thinks that it could not under any circumstances be driven over an obstruction a yard in height. The most interesting of all its characteristics is its horns. These appendages are given to both male and female, but in the latter they are scarcely more than rudimentary till they are fully adult, and even then the horns are quite insignificant. In both sexes the horn is hollow, like that of the goat and the ox, and it is deciduous, like the antlers of the deer. Altogether this is a most interesting animal, occupying an intermediate place between ruminants with hollow and persistent horns, and those with solid and persistent ones. In skin and coat it is like the deer. Its eye is most like that of some of the antelopes. Its glandular system is most like that of the goat. In salaciousness it even excels the goat.

Process for Condensing Beer.—The process for condensing beer was recently explained by Dr. Bartlett, in a paper read before the London Society of Arts. Essentially it is the same as the process for condensing milk; the only difference between the two consists in the provision made, in beer-condensing, to save the alcohol. The apparatus employed consists of a copper vacuum-pan, with which is connected a condensing-worm. Two copper globes are attached for collecting the alcohol. A certain quantity of beer being pumped into the pan, a vacuum of twenty-five or twenty-six inches pressure is maintained, and a temperature of 130°–160° Fahr. during the first stage of the process. In a short space of time all of the alcohol flows into the lower globe, the connection between which and the upper is then closed. Thus the alcohol is collected without breaking the vacuum. This alcohol contains all the delicate flavors of the beer. The alcohol having been removed, the removal of water goes on till the beer is reduced to a semifluid state. In this way thirty-six gallons of beer is concentrated into a bulk of little over two gallons, and besides there is a little over two gallons of proof-alcohol.

When the condensed extract is taken from the vacuum pan and cooled, the alcohol is mixed with it. All the aromas and volatile matters that went over with the alcohol are thus returned to the extract. Every valuable constituent of the original beer is there present, *minus* only nine-tenths of the water. When it is desired to remake the beer, all that is required is to empty one of the tin cans of condensed beer, and make it up to the thirty-six gallons by the addition of water. The product is "flat," but carbonic-acid gas can be reproduced in it to any extent that may be desired by the addition of a little yeast or uncondensed beer. The total expense of condensing beer does not exceed the sum of fifty cents per barrel, and that of remaking about twice that sum.

Damming of Streams by Drift-Ice.—In the *American Journal of Science and Art* for March, Prof. J. D. Dana remarks upon certain phenomena attending the spring overflows of Connecticut rivers, and in these finds reasons for believing that, during the breaking up of the long glacial winter, the gaps, gorges, or narrows, along the river-courses, would have been liable to obstruction by floating ice. Such obstruction, he says, would have been of all grades, from that which could simply impede the free flow of the waters, to the nearly perfect dam. In particular cases the obstructions

might have existed during a very long time, instead of for a few weeks, as happens after a modern winter. Again, the slackened or suspended flow of the water, caused by such ice-obstructions, would have favored the deposition and accumulation about them of drift, and some may have thus been converted into complete dams. This process might occasionally have wholly filled with earthy material a gorge or narrow valley—as in the Niagara River—so as to block up and divert the course of the stream.

In view of these probable conditions of the river-valleys during the glacial flood, the question arises whether the height of the upper terraces *above the narrows*, on the rivers of Connecticut, was not partly owing to the existence of ice-obstructions. That this was so seems highly probable; and the height of modern spring-floods in the Connecticut at Middletown and Hartford is now often due, in part, to this very cause. If such obstructions existed in the Thames, Connecticut, and Housatonic Valleys, they were only partial obstructions, for in the case of each the terrace of the valley below the narrows *declines quite gradually in height* from the level above the narrows, instead of abruptly. Moreover, the material of the terraces below the narrows is like that above. Further evidence of the existence of such ice-barriers is to be looked for in a distribution of gravel and large bowlders across the valley just above the narrows, where the ice-masses had been brought to a stop and piled up. Prof. Dana has as yet observed no satisfactory evidence of this kind, but thinks the question needs more investigation.

Where the Army-Worm Moth lays its Eggs.—The mode of oviposition in *Leucania unipuncta* (the army-worm moth) was, till the other day, an unsolved problem in entomology. During the current year Prof. C. V. Riley, State Entomologist of Missouri, undertook the methodical investigation of this subject, and at the meeting of the St. Louis Academy of Science, on May 1st, was able to announce that his researches had been entirely successful. Guided by the structure of the ovipositor, Mr. Riley concluded that the moth would naturally secrete the eggs where they could not be easily seen. This conclusion was afterward verified by direct observation, the author having witnessed the mode of oviposition on blue grass. The eggs are, as he surmised, secreted, being either glued in rows of from five to twenty in the groove which is formed by the folding of the terminal grass-blade, or else between the sheath and the stalk. The eggs are white, slightly iridescent, spherical, .02 inch in diameter. They are fastened to each other and to the leaf, and covered along the exposed portion by a white, glistening, viscid substance. As they mature the color becomes yellowish, and by the seventh day the brown head of the embryo shows distinctly through the shell. The larva emerges from the eighth to the tenth day, is 1.7 millimetre in length, dull, translucent white in color, with a large black-brown head, and is a looper, the two front pairs of abdominal prolegs being atrophied. On account of its extremely small size and of the color resembling the pale bases of the grass-stalks near the ground, it is almost impossible to find them even where they are numerous. The one great economical result of these researches is the indicating of an effectual mode of destroying the army-worm—viz., burning the eggs with the stubble.

How the Mississippi wears away its Banks.—The observation is made by Reclus, in his work "The Earth," that the Mississippi River seems to contradict the law of displacement of running water, which in consequence of the motion of the earth on its axis causes all streams which flow north or south to hug the west side of their valleys. But Mr. G. W. R. Bailey, in a paper published in the *Journal of the American Society of Civil Engineers*, shows that the anomaly is an apparent one only. "The river," he writes, "does wear away its western shoreline more rapidly than the eastern, but it cannot do otherwise than gradually excavate circular bends, of from twenty to twenty-five miles in circumference generally, and then cut them off, leaving them to the westward. There has been, always, an excess of overflow and of sedimentary deposits west, and by far the largest number, as well as the greatest bends when cut off, have been left to the west. The western portion

of the valley is everywhere well filled with alluvion, and the swamps west have firm bottoms throughout the valley. Below Baton Rouge, where the river tends to the southeast, the swamps on the east are boggy and not well filled with deposits, and the large spaces covered by Lakes Maurepas and Pontchartrain are left unfilled.

"If the Mississippi had been a river of clear water (instead of being sedimentary), traversing a valley not alluvial, it would probably occupy the western side of its valley like other streams flowing toward the equator; but, as it is, it levees or embanks itself to the eastward by an excess of deposits west. It hugs the bluffs on the east side, down to the last one at Baton Rouge, for the reason that it could not be forced any farther eastward; but immediately below the last bluff, the excess of deposits west crowded the river-channel eastward still farther; the general direction thence to the present mouth being southeast. The mouth of the river having now reached very deep water in the Gulf of Mexico, and having advanced a little beyond the filling up of the gulf west, and beyond the southern limit of the western highlands, the tendency is to flow westward by the Southwest Pass, which is now the largest channel, conveying about one-third of the whole river to the sea."

Glacial Phenomena.—Prof. A. R. Grote recently delivered a lecture on "The Ice Age" before the Catholic Institute of Buffalo. He first called attention to the evidences of glacial action in the limestone rock underlying the surface deposit of sand, gravel, and clay, in that region. Another evidence of glacial action is the presence of erratic blocks; these too are found in the vicinity of Buffalo. In Europe the largest of these erratic blocks have been traced to their original site. Near Zürich, in Switzerland, there is a block estimated to weigh nearly 5,000 tons. Another block, of nearly equal weight, may be seen at Neufchâtel. By comparing their grain, structure, and form, it has been ascertained that they came from the Alps, and indeed the very ledge of rock of which they were once a part has been determined. To reach their present location they must have traversed what are now bodies of water, as the Lake of Geneva. Such blocks, of all sizes, being held fast in the ice at the bottom of the glacier, act as chisels on the rock beneath, producing scratches. And, as a river accumulates piles of sticks and rubbish along its banks, so does the glacier accumulate piles of stones and clay, known as *moraines*. *Medial* moraines are found where two glacial streams unite, just as a sand-bar marks the junction of two rivers. These medial moraines are extensions of *lateral* moraines which are found at the sides of the glacier. *Terminal* moraines are found at its mouth. Over the south-western portion of the State of New York, bowlders have been found which have come from the Lake Superior region, some of them containing copper-ore. Bowlders of transportation have also been found on the summit of Mount Washington, which is more than 6,200 feet high, showing that the glacier must have at one time overtopped this summit. The direction of the scratches shows that the general course of the ice-mass was from north to south. There was a glacier of the Connecticut, the Hudson, and the Alleghany Valleys. The ice occupied the place of the water-courses, and underneath it streams flowed to the sea.

Lieutenant Cameron's Explorations.—Lieutenant Cameron has returned safely to England from his memorable journey of exploration in Central Africa. He explored the head-waters of the Congo, an immense river-system, one of the feeders of which is the Lualaba, which drains Lake Tanganyika into the Congo, and which Livingstone supposed to be a tributary of the Nile. The Congo and its tributaries constitute one of the grandest systems of internal water-communication in the world. As to the wealth of the newly-explored country, Cameron describes it as enormous. From its mineral resources and agricultural capabilities it seems destined to become one of the granaries of the world, a centre of civilization, and the scene of iron manufactures when other parts of the world have been exhausted.

Antiseptic Properties of Thymol.—The following notes of experiments made by L. Lewin to determine the antiseptic and antifermentative properties of thymol we translate from *Gaea*. This substance, thymol, ob-

tained by distillation from oil of thyme, occurs in white, highly-aromatic crystals; when dissolved in hot water in the proportion of one part per 1,000 it forms a fully-saturated solution possessing a neutral reaction. More concentrated watery solutions cannot be obtained, for, when dissolved in greater proportions than one in 1,000, the thymol evaporates. Lewin finds that 0.1 per cent. of this solution is sufficient to prevent fermentation in sugary liquids, no matter what the proportion of sugar and yeast. Milk to which a small quantity of the thymol solution was added did not begin to show signs of coagulation till twenty days later than milk with which an equal quantity of water had been mixed. Filtered white of egg in contact with the air was found to grow putrid in three or four days, whereas white of egg with which thymol-water had been mixed gave not the slightest indication of putridity after eleven weeks. The same results were obtained in treating pus with water and thymol: pus so treated at once lost its putrid odor, and continued to be odorless for five weeks, or until it had become dry.

The English Commission on Vivisection.—The Royal Commission appointed in England to inquire into the subject of experimentation on living animals, for scientific purposes, have reported unanimously against the absolute prohibition of this practice. "Our conclusion is," says the report, "that it is impossible altogether to prevent the practice of making experiments upon living animals for the attainment of knowledge applicable to the mitigation of human suffering or the prolongation of human life; that the attempt to do so could only be followed by the evasion of the law, or the flight of medical and physiological students from the United Kingdom to foreign schools and laboratories, and would, therefore, certainly result in no change favorable to the animals; that absolute prevention, even if it were possible, would not be reasonable; that the greatest mitigations of human suffering have been in part derived from such experiments; that by the use of anæsthetics in humane and skillful hands the pain which would otherwise be inflicted may, in the great majority of cases, be altogether prevented, and in the remaining cases greatly mitigated; that the infliction of severe and protracted agony is in any case to be avoided; that the abuse of the practice by inhuman or unskillful persons—in short, the infliction upon animals of any unnecessary pain—is justly abhorrent to the moral sense of Englishmen generally, not least so of the most distinguished physiologists and the most eminent surgeons and physicians; and that the support of these eminent persons, as well as of the general public, may be confidently expected for any reasonable measures intended to prevent abuse."

Perception of Musical Tones.—From the researches of Prof. Preyer, of Jena, on the "Limits of Perception of Musical Tones," it appears that the minimum limit for the normal ear is from sixteen to twenty-four vibrations per minute, and the maximum forty-one thousand vibrations, though persons with average powers of hearing were found to be absolutely deaf to tones of sixteen thousand, twelve thousand, or even fewer vibrations. Silence, according to Preyer, is a state of uniform minimum excitation of the auditory nerve-fibres. Silence is to the ear precisely what black is to the eye. The pressure of the fluid contents of the labyrinth and the flow of blood through the vessels must give rise to sensations of which we are unconscious only because of their uniformity, their constancy, and their low degree of intensity. Silence, when the attention is concentrated on the sense of hearing, is found to vary in degree just as the blackness of the visual field, when light is excluded from the eye, has been observed to vary. Lastly, the parallel between the auditory sense and the visual is borne out by a study of the entotic (intra-aural) sensations, which are closely analogous to well-known entoptical (or intra-ocular) phenomena.

Dr. Mohr on the Source and Composition of Meteorites.—From an examination of a large number of meteorites, Dr. Mohr, in Liebig's *Annalen der Chemie*, concludes that these bodies must have been formed upon a planet warmed by the sun, or by a sun in absolute rest, and in the lapse of an enormous length of time. Under what circumstances this planet has been shivered

into fragments does not appear. It must have had a large collection of waters, a sea, which has likewise been dispersed, and which now is to be found in meteoric swarms, and in comets. The peculiarity of meteorites, as compared with our globe, consists, he says, in the circumstance that we find in the former more products of reduction, and, except the earths, no perfect oxides. Thus, in meteorites we find no ferric oxide, but metallic iron, sulphide of iron, and phosphide of nickel-iron. Upon our globe phosphorus occurs only as phosphoric acid. Hence the hypothetical planet where the meteorites originated must have been smaller than our globe, and have had a less dense atmosphere containing less free oxygen. The specific gravity of most meteorites agrees with the calculated density of the planetoids between Mars and Jupiter.

A Sound-producing Spider.—In the "Proceedings" of the Bengal Asiatic Society is given an account of a gigantic stridulating spider, from Assam. The sound-producing apparatus of this spider (a species of *Mygale*) consists of a *comb*, composed of a number of highly-elastic chitinous rods, situated on the inner face of the so-called maxillæ, and of a *scraper*, formed of an irregular row of sharp spines on the outer surface of the antennal claws. This apparatus is equally well developed in both sexes, as in most coleopterous insects, and is not confined to the males, as in the *Orthoptera*, *Homoptera*, and the stridulating spiders (*Theridion*), observed by Westring, in all of which the exclusive purpose of the sounds seems to be to charm or call the opposite sex.

NOTES.

The Royal Society of London has received from Mr. Phillips Jodrell £6,000 to be applied, principal as well as interest, to the encouragement of original research in the physical sciences. Mr. Jodrell's object in making this gift is to ascertain, by practical experiment, to what extent the progress of original research is retarded in England by the want of public support, and in what form an increased measure of support would be most likely to promote its development.

Chlorine was first employed industrially by Robert Hall, at White's bleach-works, near Nottingham. He procured from Germany a vial of chlorine-water, but the first experiment was not successful. The solution, being too strong, destroyed the fabric, but by degrees the new agent became manageable. The use of lime by Tennant, of Glasgow, in 1798, as an absorbent of chlorine, seems to have over-shadowed these early results.

In the *Tribune* mention is made of a paper recently read before the French Academy of Inscriptions, upon the determination of the age of the third pyramid at Ghizeh. It appears that M. Chabas, an Egyptologist, has succeeded in deciphering in the Ebers papyrus a certain hieroglyph, which he finds to represent the name of Menkeres, the builder of that pyramid. An astronomical note in the manuscript states that the heliacal rising of Sothis (the star Sirius) occurred in the ninth year of the reign of Menkeres. The astronomer Biot now made calculations to fix the time of this heliacal rising of Sirius, and found that it must have taken place between the years 3010 and 3007 B. C.

Dr. W. B. Richardson attributes the high vitality of Jews, as shown in statistics, to their strict observance of certain sanitary laws respecting diet, cleanliness, and abstinence from strong drink.

A Tasmanian correspondent of *Nature* relates an instance of extraordinary tenacity of life exhibited by an eel. Seven years ago an eel, which had been slightly injured, was placed along with other eels in a tank from which they were taken as required. This tank was fitted with finely-perforated zinc at each end, through which nothing but the most minute organisms could pass; otherwise it was perfectly tight. The injured eel was left after the others had been taken out, and so on again and again, when other lots were put in and removed. "It is still in the tank, perfectly transparent, and quite white, and is to all appearance healthy and lively enough."

Died, March 2, 1876, in Washington, at the early age of twenty-eight years, Archibald R. Marvine. In an obituary notice, published in the *American Journal of Science and Arts*, it is stated that Mr. Marvine graduated in 1870 from the Hooper Mining School, Harvard University; the same year he accompanied the Santo Domingo Expedition as assistant geologist; in 1871 he served as astronomer to the Wheeler Expedition, at the same time doing work as a geologist; in 1873 he was appointed geologist of the Hayden Survey Expedition. The hardships and privations he endured in the wilderness of Colorado undermined his health, and since the early winter of 1874–'75 he had been incapacitated for field-work.

The decrease in the number of small-pox cases in the Punjab, since the introduction of vaccination, is very striking. In 1869

there were 53,195 deaths; in 1871, 25,534; in 1874, 12,026. That this decrease is due to vaccination is shown from the fact that in the northern districts, where vaccination is in greater favor with the people than in the southern, the rate of small-pox mortality per 1,000 is 1.31, while in Umballa and six other southern districts the rate is 2.05.

THE scientific results of the Polaris Expedition are nearly ready for publication. They will form four volumes, the first three of which, edited by Dr. Emil Bessels, will be devoted to hydrography, meteorology, and astronomy. The fourth volume, of which Admiral Davis has charge, will contain a narrative of the expedition and much biographical information.

A NEW industry has been introduced in France—the breeding of ants for their eggs. These eggs are sold to the breeders of pheasants. As yet the business is in the hands of its originator, a woman, and she already appears to be on the high-road to fortune.

FROM experiments made by Scolosuboff, it appears that dogs can absorb with impunity about sixteen times as much arsenic (in proportion to their weight) as would kill a human being.

THE cinchona-tree has been introduced successfully into the island of Réunion. The cinchona-seeds were first sowed near the coast, and the young trees which grew from them were subsequently conveyed to an altitude of from 2,000 to 2,500 feet. There they thrive so well that in four years' time some of them grew to the height of twenty-one feet.

IN the annual report of Prof. Henry it is stated that the Smithsonian Institution fund now amounts to $717,000. It is contemplated to authorize a series of experiments to determine accurately the rate of increase of the earth's temperature at progressive depths. Another project embraces new and careful experiments on the velocity of light. The work of ascertaining the weight of the earth by Cavendish's method will also probably be undertaken anew.

IN the milk of cows affected by the foot and mouth disease, there is a marked tendency of the fat-globules to aggregate. The latter are also much larger than in healthy milk, and in advanced stages of the disease rise to the surface, not as cream, but as pure butter-fat. The film enveloping the particles of fat presents a glairy, mucus-like appearance, and is intensely refractive. It is only necessary to agitate a strongly-affected sample of the milk for a few minutes in order to obtain from a pint of milk a lump of butter weighing an ounce or more.

GERMAN manufacturers are purchasing the fish-bones gathered along the Norwegian coast at the great fish-curing stations. The bones make a good fertilizer, and when pulverized by suitable machinery at the point of collection are readily transported. It is estimated that the bone-product of the establishments in Newfoundland amount to 20,000,000 pounds a year.

DR. R. ANGUS SMITH advocates the culture of peat as a fuel. In the Grampian Hills he finds a bog, the annual product of which is ten tons of dry peat—equal to four tons of coal. By proper treatment it is possible to grow the material much faster than this. Indeed, the product of the bog mentioned above is considered to be far below the average.

EXPLOSIONS of fire-damp in coal-mines are found to occur most numerously in times of low atmospheric pressure. When the pressure is great, the carburetted hydrogen is prevented from issuing from the walls and sides of the coal-seam; but when the pressure is suddenly lessened the gas escapes, and accumulates until sometimes it reaches the proportion sufficient with common air to form an explosive mixture.

MR. HENRY S. DRINKER, of Philadelphia, mining engineer, is preparing a work on "American Tunnels and Tunneling," and has sent out a circular in which he requests that data concerning railroad tunnels, mining tunnels, headings, and drifts, be forwarded to him, so as to make the work as complete as possible. Mr. Drinker's address is 1,906 Pine Street, Philadelphia.

APPLYING to the elephant Flourens's mode of estimating the natural duration of an animal's life, viz., multiplying by five the number of years requisite to perfect its growth and development, Sir J. Emerson Tennent fixes the term of life for that great pachyderm at (thirty by five) a hundred and fifty years. Maturity is shown by the consolidation of the bones of the animal with the epiphyses, and in the elephant this consolidation is complete at the age of about thirty.

IN the seal-fishery an enormous amount of wholesome meat is annually wasted. Only the blubber and skins of the seals are brought away. It is proposed to have the meat put up in tin cans at Disco, and so shipped to Europe for food.

A MOVEMENT is on foot to bring about a uniformity of measures, instruments, and methods of observation, among physicians in all countries. It is proposed to ask the next International Medical Congress to constitute national commissions for the purpose of deciding upon the most practical means of attaining this object.

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